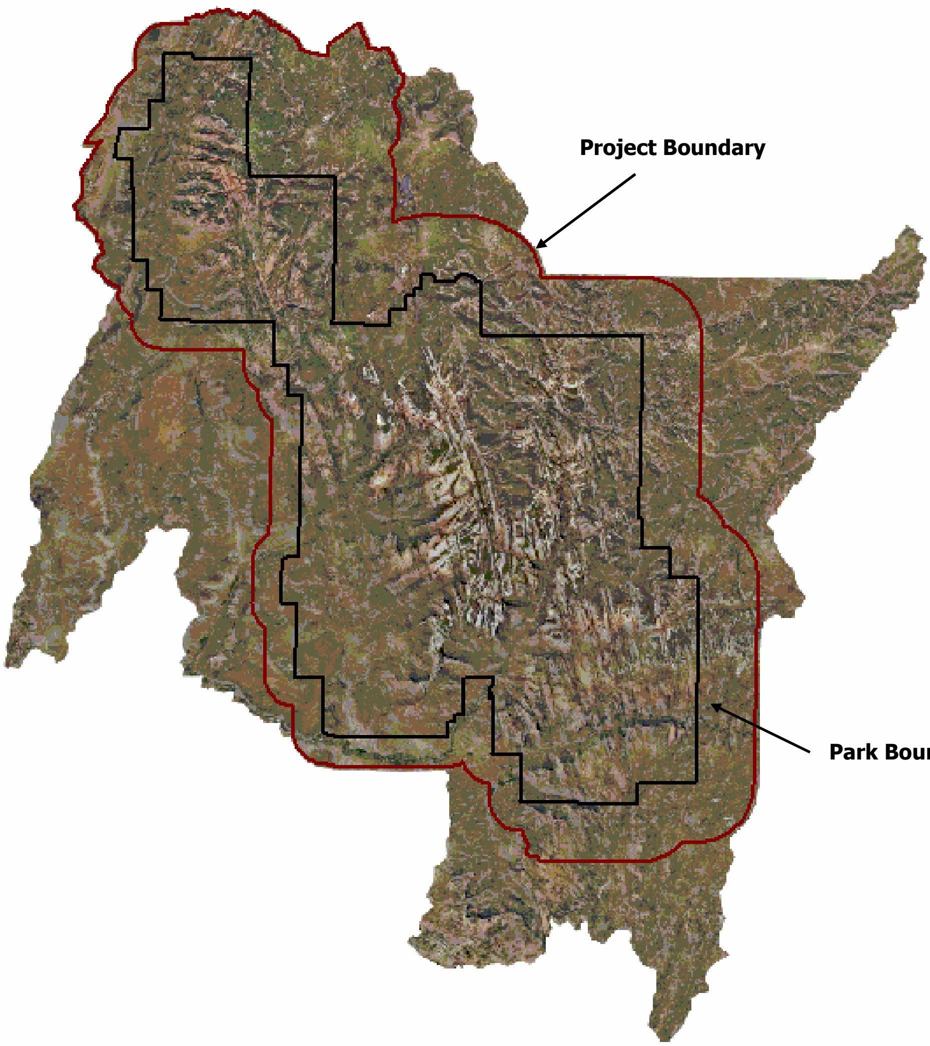
Zion National Park, Utah
1999-2003 VEGETATION MAPPING PROJECT



FINAL REPORT -- MARCH 31, 2004

Technical Memorandum 8260-03-01

Remote Sensing and GIS Group
Technical Service Center
Bureau of Reclamation
Denver, Colorado

USGS-NPS VEGETATION MAPPING PROGRAM

Zion National Park, Utah

Dan Cogan
Program Lead
Bureau of Reclamation
Remote Sensing and GIS Group
Denver, Colorado

Marion Reid
NVC Lead
Senior Regional Ecologist NatureServe
Boulder, CO

Keith Schulz
NVC Ecologist
Vegetation Ecologist NatureServe
Boulder, CO

Mike Pucherelli
Group Manager
Bureau of Reclamation
Remote Sensing and GIS Group
Denver, Colorado

Report Produced by:
U.S. Bureau of Reclamation
Technical Service Center
Remote Sensing and GIS Group
Mail Code D-8260 Denver Federal Center Building 56
Denver, Colorado 80225

Program Managed by:
U.S. Geological Survey
Center for Biological Informatics
Denver Federal Center, Building 810
Room 8000, MS 302
Denver, Colorado 80225-0046

In Cooperation with:

U.S. National Park Service **U.S. Geological Survey** **NatureServe (formerly ABI)**

This report was prepared for the U.S. National Park Service and the U.S. Geological Survey's Center for Biological Informatics by the Remote Sensing and Geographic Information Group of the Bureau of Reclamation's Technical Service Center, Denver, Colorado
Technical Memorandum No. 8260-03-01.

U.S. Department of the Interior
Mission Statement

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

Mission of U. S. Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The Remote Sensing and Geographic Information Group, organized in 1975, provides assistance and advice regarding the application of remote sensing and geographic information systems (GIS) technologies to meet the spatial information needs of the Bureau of Reclamation and other governmental clients.

TABLE OF CONTENTS

LIST OF TABLES

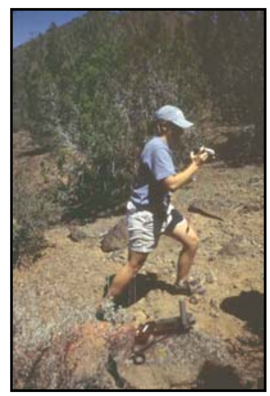
LIST OF FIGURES

LIST OF CONTACTS AND CONTRIBUTORS

U. S. Department of the Interior
United States Geological Survey -
Biological Resources Division

Karl Brown
Program Coordinator - USGS-NPS Vegetation
Mapping Program
U.S. Geological Survey
Center for Biological Informatics
P.O. Box 25046
Denver, Colorado 80225-0046
Phone (303) 202-4240
E-Mail: karl_brown@usgs.gov
Website: http://biology.usgs.gov/cbi

Contributors: Susan Stitt and Tom Owens



Jim Drake
Midwest Regional Office
Project Manager
1313 Fifth Street, S.E. #314
Minneapolis, Minnesota 55414
Phone: (612) 331-0729
E-Mail: jim_drake@natureserve.org

Marion Reid
Western Regional Office
Senior Regional Ecologist
2060 Broadway Suite 230
Boulder, Colorado 80302
Phone: (303) 541-0342
E-Mail: marion_reid@natureserve.org

Keith Schulz
Vegetation Ecologist
Phone: (303) 541-0356
Email: keith_schulz@natureserve.org


Unknown Plant ID Team

U. S. Department of the Interior
U.S. National Park Service

Mike Story
NPS Program Coordinator
NPS-WASO Natural Resource Information
Division I&M Program
Phone: 303-969-2746
E-mail: mike_story@nps.gov
Website:
http://biology.usgs.gov/npsveg/index.html

Jeff Bradybaugh
Research and Resource Management Supervisor
Zion National Park
SR 9
Springdale, UT 84767-1099
Phone: 435-772-0208
E-Mail: jeff_bradybaugh@nps.gov
Website: http://www.nps.gov/zion

Henry Bastian
Fire Effects, Zion Fire Program
Phone: 435-772-0193
E-mail: henry_bastian@nps.gov

Contributors: Dan Cohan, Elena Robisch, Denise Louie

U. S. Department of the Interior
Bureau of Reclamation

Michael Pucherelli
Group Manager
Remote Sensing and Geographic Information Group
Mail Code D-8260 Denver Federal Center
Building 56
Denver, Colorado 80225
Phone: (303) 445-2267
E-mail: mpucherelli@do.usbr.gov
Website: http://www.usbr.gov/tsc/rsgis

Trudy Meyer
Lead GIS Specialist
Phone: 303-445-2278
Email: tmeyer@do.usbr.gov

Dan Cogan
Program Lead
Phone: (303) 445-2291
E-mail: dcogan@do.usbr.gov

Contributors: Alan Bell, Janet Coles, Doug Crawford, Jean Pennell,

Other Contributors (Various affiliations):

Dr. Stanley Welsh
Dr. Duane Atwood
(Brigham Young University)
Jim Von Loh
Dr. William Reid
Susan Hobbs
Julie Thompson
Kelly Lewelling
Steve Chubback
Buddy Smith

ACKNOWLEDGEMENTS

Dramatic and awe inspiring Zion National Park with its colossal sandstone cliffs, isolated towers, and deep, narrow canyons is a naturalist's dream but a mapper's nightmare. Undaunted by the task of classifying and mapping an area with what is called "the richest diversity of plants in Utah" were a top-notch team of assembled ecologists, botanists, park personnel, GIS and mapping professionals, and numerous support staff. Although a rather informal and dynamic bunch, the "Zion Veg Mapping Team" achieved their objective of classifying and mapping Zion's plant communities-- and to all of them goes my warmest heartfelt thanks.

I feel very privileged to have worked on this project with the following people and would like to personally thank them and their respective organizations for their assistance:

-Dan Cohan formerly with Zion now with the U.S. Fish and Wildlife Service, was an immense help with the GIS, GPS, and logistical support at Zion. Without Dan, the helicopter trip would never have gotten off the ground, literally.

-My colleagues Janet Coles and Jim Von Loh (now with E2M consulting) for their valuable assistance with the photo interpretation, plot and verification data collection, report and data review, and lending their ecological wisdom.

-Henry Bastian with the Zion Fire Program was a great local resource throughout all levels of this project and relentlessly reviewed all of my draft material.

-Jeff Bradybaugh, at the helm of Zion's Research and Resource Management Division, had nothing but staunch support and never-ending patience for this project.

- Special recognition goes to Julie Thompson and Kelly Lewelling and all of the field folks, who mainly on their own spent untold hours hiking/climbing/canyoneering all over Zion in order to obtain the necessary plot, accuracy assessment, and photo verification data.

-Bill Reid not only helped collect plot data, but also wrote progress reports, interpreted images, took extensive notes, entered data, wrote a newspaper article and provided much-needed comic relief, all from a guy who just wanted to be a volunteer.

-Becky Morton and the dependable staff at Horizons Inc., Rapid City, SD for obtaining excellent aerial photography and imagery.

-Keith Schulz, Marion Reid, and Michael Schindel of NatureServe and The Nature Conservancy were integral to the gradsect analysis, collecting plot data, writing/reviewing this report, and creating the National Vegetation Classification System for Zion.

-Tom Owens, Karl Brown of the USGS and Mike Story with the NPS for bringing this project to the BOR and then being there for help with coordination, logistics, and financial matters.

-The entire staff of BOR RSGIS (both past and present) for so many things especially Trudy Meyer for making sense of all my line-work and Kurt Wille for his help with ArcGis and 3D graphics.

- dan.

LIST OF ABBREVIATIONS AND ACRONYMS

AA	Accuracy Assessment
AML	Arc Macro Language
BOR	Bureau of Reclamation (also USBR)
BRD	Biological Resource Division (of the USGS)
CBI	Center for Biological Informatics (of the USGS/BRD)
CIR	Color Infrared Photography
DEM	Digital Elevation Model
DLG	Digital Line Graph
DRG	Digital Raster Graphic
DOQQ	Digital Orthophoto Quarter Quadrangle
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System(s)
GPS	Global Positioning System
MMU	Minimum Mapping Unit
NPS	U.S. National Park Service
NAD	North American Datum
NBII	National Biological Information Infrastructure
NRCS	Natural Resources Conservation Service (formerly the Soil Conservation Service)
NVC	National Vegetation Classification
NVCS	National Vegetation Classification System
NWI	National Wetland Inventory
PLGR	Precision Light-Weight GPS Receiver
RSGIS	Remote Sensing and Geographic Information Group
TNC	The Nature Conservancy
USBR	United States Bureau Of Reclamation (also BOR)
USDA-SCS	U.S. Dept. Of Agriculture – Soil Conservation Service
USFS	United States Forest Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
ZION	Zion National Park

EXECUTIVE SUMMARY

Zion National Park (ZION) encompasses 229 square miles in Southwest Utah, stretching across portions of the Colorado Plateau, Great Basin, and Mojave Desert regions of the United States. Between 1999 and 2003 an ambitious project was conducted to accurately classify and map ZION's unique assemblage of plant associations. This report documents those efforts.

To complete the daunting task of mapping the diverse vegetation at ZION, a multi-year program was initiated. This consisted of two linked phases: (1) vegetation classification using the National Vegetation Classification System (NVCS) and (2) digital vegetation map production directed by NatureServe and the U.S. Bureau of Reclamation's (BOR) Remote Sensing and GIS group, respectively. To classify the vegetation, we sampled 346 representative plots located throughout the 246,452-acre (99,738 ha) project area (park + environs) during the summers of 1999 and 2000. Analysis of the plot data using ordination and clustering techniques produced 95 distinct plant associations, 44 of which were newly described at ZION.

To produce the digital map, we used a combination of 1999 1:12,000-scale true color aerial photography, 1999 1:12,000-scale true color ortho-rectified imagery, and 3 years of gound-truthing to interpret the complex patterns of vegetation and land-use at ZION. In the end, 76 map units were developed and directly cross-walked or matched to corresponding plant associations and land-use classes. All of the interpreted and remotely sensed data were converted to Geographic Information System (GIS) databases using ArcInfo© software. Draft maps created from the vegetation classification were field-tested and revised before independent ecologists conducted an assessment of the map's accuracy during 2001-2003. The accuracy assessment revealed an overall database accuracy of 82%.

Products developed for Zion National Park are described and presented in this report and are stored on the accompanying CD-Rom, these include:

- A Final Report that includes a vegetation key, accuracy assessment information, and a photo interpretation key;
- A Spatial Database containing vegetation, plots, accuracy assessment, and flight line index layers;
- Digital Photos (scanned from 35mm slides) of each vegetation type along with representative ground photos and miscellaneous Park views;
- Printable Graphics of all spatial database coverages;
- Federal Geographic Data Committee-compliant metadata for all spatial database coverages and field data.

In addition, ZION and the USGS CBI both received copies of:

- 9x9 inch Aerial Photos;
- Uncompressed Digital Orthophotos;
- Digital data files and hard copy data sheets of the observation points, vegetation field plots, and accuracy assessment sites;
- Hardcopy, paper vegetation maps.

The CD-Rom attached to this report contains text and metadata files, keys, lists, field data, spatial data, the vegetation map, graphics, and ground photos. The USGS will post this project on its website: http://biology.usgs.gov/npsveg/index.html

For more information on the NVCS and NVC associations in the U.S. please go to NatureServe's website: http://www.natureserve.org.

For more for information on other projects completed by the BOR, visit http://www.usbr.gov/tsc/rsgis.

1. INTRODUCTION

1.1 Background

USGS-NPS Park Vegetation Mapping Program

In 1994, the U.S. Geological Survey (USGS) and National Park Service (NPS) formed a partnership to map National Parks in the United States using the National Vegetation Classification System (NVCS). The goals of the USGS-NPS Vegetation Mapping Program are to provide baseline ecological data for park resource managers, create data in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities (FGDC 1997, Grossman et al. 1998, http://biology.usgs.gov/npsveg/index.html).

Central to fulfilling the goals of this national program is the use of the National Vegetation Classification System (NVCS) as the standard vegetation classification system. This system:

- is vegetation based;
- uses a systematic approach to classify a continuum;
- emphasizes natural and existing vegetation;
- uses a combined physiognomic-floristic hierarchy;
- identifies vegetation units based on both qualitative and quantitative data;
- is appropriate for mapping at multiple scales.

The use of standard national vegetation classification system and mapping protocols facilitate effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information support a wide variety of resource assessment, park management, and planning needs, and provide a structure for framing and answering critical scientific questions about vegetation communities and their relationship to environmental processes across the landscape.

The NVC has primarily been developed and implemented by The Nature Conservancy (TNC) and the network of Natural Heritage Programs over the past twenty years (Grossman et al. 1998). Currently it is maintained and updated by NatureServe (formally ABI-Association for Biological Information). Additional support has come from federal agencies, the Federal Geographic Data Committee (FGDC), and the Ecological Society of America. Refinements to the classification occur in the process of application, leading to ongoing proposed revisions that are reviewed both locally and nationally. TNC and now NatureServe has made available a 2-volume publication presenting the standardized classification, providing a thorough introduction to the classification, its structure, and the list of vegetation types found across the United States as of April 1997 (Grossman et al. 1998). This publication can be found on the Internet at: http://www.natureserve.org/publications/library.jsp.

NatureServe has since superceded Volume II of the publication (the classification listing), providing regular updates to ecological communities in the United States and Canada. This online database server, NatureServe Explorer®, can also be found on the Internet at: http://www.natureserve.org/explorer.

Zion National Park Vegetation Mapping Project

The specific decision to map the vegetation at Zion National Park (ZION) as part of the U.S. Vegetation Mapping Program was made in response to the NPS Natural Resources Inventory and Monitoring Guidelines issued in 1992. Under these guidelines, Zion was viewed as a top-priority Park based on its need for the program's vegetation map products. Driving this need was the Park's inability to spatially analyze the vegetation at a fine enough scale to accurately predict various management issues. Central to their concerns were the need for modeling the spread and intensity of fire and calculating habitat for endangered and threatened species.

In 1999 the USGS Center for Biological Informatics (CBI) kicked-off this project by asking the U.S. Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIS) to undertake the mapping portion of this project. At this time NatureServe was also contracted to conduct both the fieldwork and classification stages. As the project progressed, other contracted and volunteer botanists, ecologists, geologists, and various Park personnel were incorporated.

NatureServe, BOR RSGIS, and the Park ultimately formed a three-part vegetation team each responsible for a specific portion of the project as outlined by CBI (**Appendix A**). NatureServe became primarily responsible for collecting standardized field samples and using them to classify ZION's vegetation types and also to conduct an accuracy assessment on the final vegetation map. RSGIS took on the role of the mapping team responsible for aerial photo interpretation and creation of a digital vegetation map. Finally ZION staff provided logistical and technical support, helped coordinate fieldwork, and reviewed and evaluated draft data.

As a team, our objectives were to produce final products consistent with the national program's mandates. These included:

- Vegetation and map unit classifications based on the National Vegetation Classification System and ZION-specific requirements;
- A spatial database of ZION's vegetation, using remote sensing and Geographic Information System (GIS) techniques;
- Digital and hard copy vegetation maps with a minimum 80% accuracy.

1.2 Scope of Work

Vegetation mapping for ZION occurred over a 246,452-acre project boundary, encompassing both the executive boundary of Zion National Park and a 1-2 mile environ radius or buffer. The final area of interest was based mainly on reconciliation between ZION's management needs (e.g. water basin boundaries), financial constraints, and reasonable time limitations. Part of the compromise involved acquiring aerial photography and ortho-imagery for a larger area surrounding ZION than would be mapped (**Figure 1**).

1.3 Zion National Park

Located in the southwestern corner of Utah, Zion National Park stretches over 148,016 acres, ranging in elevation from 3,666 ft (1,128 m) at Coalpits Wash in the southwest corner to 8,726 ft (2,660 m), at Horse Ranch Mountain in the Kolob Canyons section. The Park lies in Washington, Iron, and Kane Counties with primary access restricted to three entrances occurring in the north along Interstate 15 (Kolob Canyons), South via Utah 9 through the town of Springdale, and from the East on Utah 9 (**Figure 3** and **Figure 4**).

Zion is well known for its massive sandstone cliffs, deep canyons, arches, and monoliths such as the Alter of Sacrifice, The Narrows, The Great Arch, and The Great White Throne. The Park draws over 2 million annual visitors to the Park, primarily visiting along the main Park roads and trails (Zion National Park Website: http://www.nps.gov/zion). ZION is a relatively large national park based on 2-dimensional land area; however it is truly immense if you consider surface area or its 3-dimensional size. The magnitude of ZION is best described by reviewing its major abiotic and biotic components as follows.

Topography

Zion National Park occurs on the Colorado Plateau in the Southwest Region of the United States. John Wesley Powell first named this area the "Colorado Plateaus", and recently the Plateau has come to be understood as a 130,000 square mile basin ringed by highlands and filled with many plateaus. Subtle environmental forces including wind and water erosion have combined to carve this area's sedimentary geological layers into a series of high plateaus, narrow sandstone canyons, and isolated towers (Hamilton, 1995) (**Figure 2**).

Occurring on the western edge of the Colorado Plateau, ZION contains many distinct geologic features common to this region. Two of the more popular are Zion Canyon in the south-central region of the Park and Kolob Canyons in the northwest (**Figure 3**). Here, the down cutting of the Virgin River, LaVerkin Creek and other tributaries have created sheer canyon walls rising over 2000 feet.

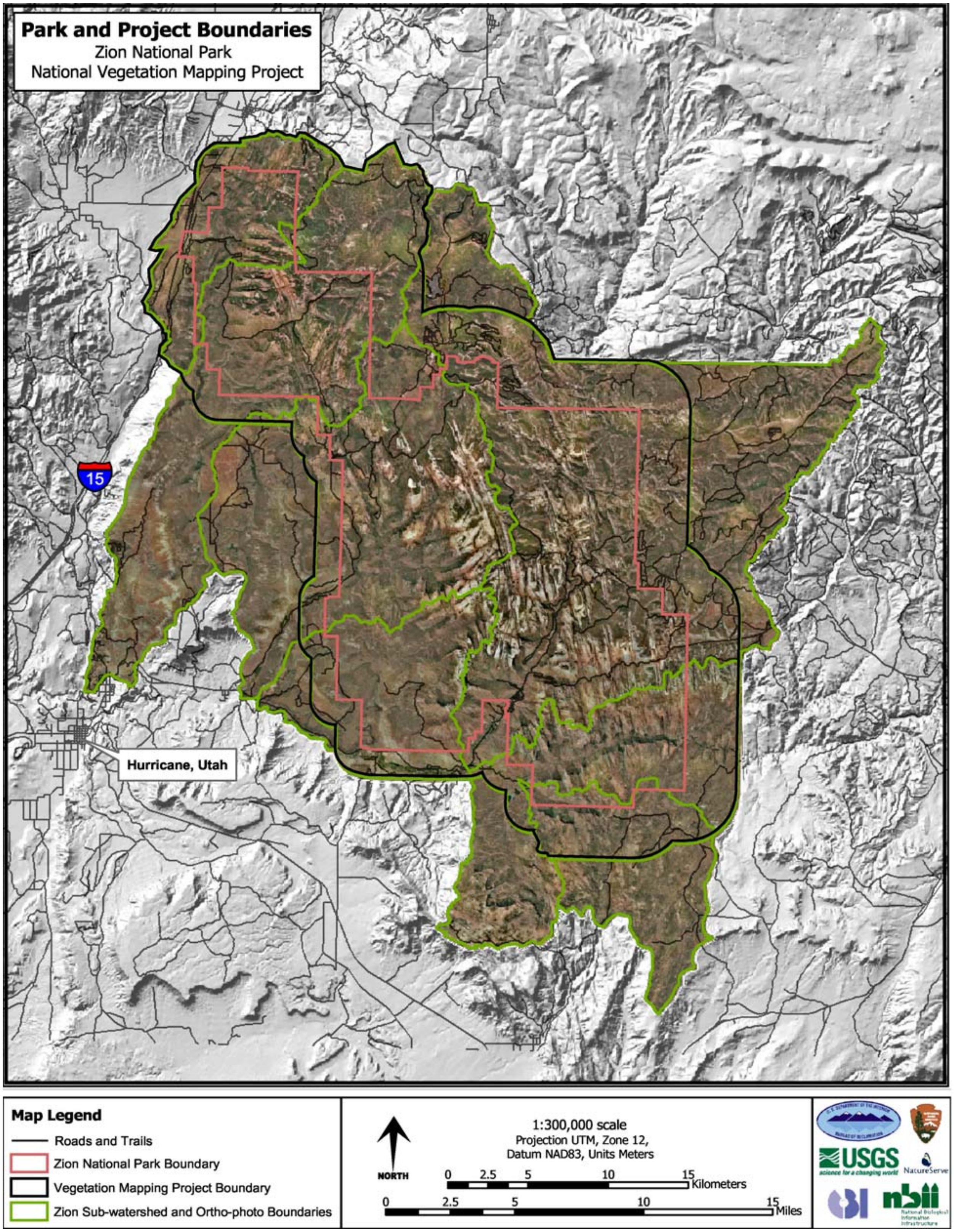


Figure 1. Vegetation Mapping Project and Park Boundaries.
(Color background image is a mosaic of the new Zion Orthophoto created for this project.)

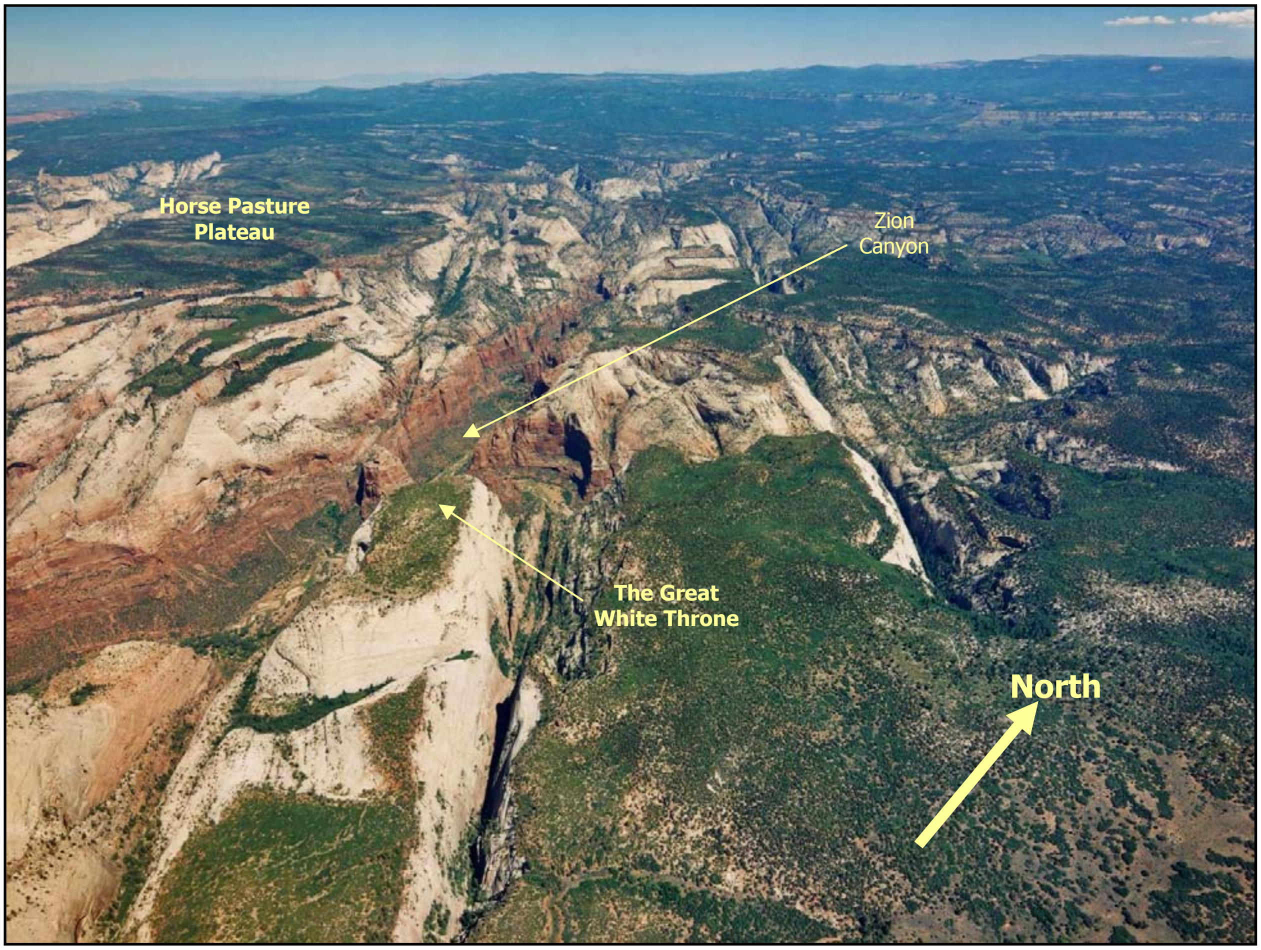


Figure 2. Oblique aerial photo of Zion National Park.
Notice the down-cutting of the Virgin River and its tributaries creating Zion Canyon, isolated towers and large plateaus.
(obtained and modified from Horizon's Inc.)

Looking at Zion by geographical sections, the South is bordered by low desert mesas intermingled with rubble-filled canyons and washes. To the North and East, ZION transitions into high plateaus covered by dense forests and tall shrublands. A mix of sandstone or slick-rock features including hoo-doos, slot canyons, and small mesas are common in the Center, and finally the West contains talus slopes covered with Pinyon–Juniper woodlands.

Geology

ZION provides a case study in identifying the nine geologic formations from the Colorado Plateau's Mesozoic era. Originally created from ancient sediments, ZION's geology has been under constant siege by erosion and volcanic events for millennia. By examining the canyon walls, one can go through time, from when this area was a vast sea, to a highly volcanic region, to an arid, sandy desert. Also apparent are the continuous processes still at work, such as wind erosion on Checkerboard Mesa, down-cutting by the Virgin River, and cinder cones and lava flows on the west side of the Park (Hamilton, 1995).

The nine major geologic formations at ZION include from oldest to youngest: Kaibab, Moenkopi, Chinle, Moenave, Kayenta, Navajo, Temple Cap, Carmel and Dakota formations. Within these formations, the Chinle is separated into the Petrified Forest and Shinarump members and the Navajo contains distinctive brown, red, and white sandstones. Also interspersed are layers of alluvium, volcanic rocks and lake, pond and slide deposits (see **Figure 5**)

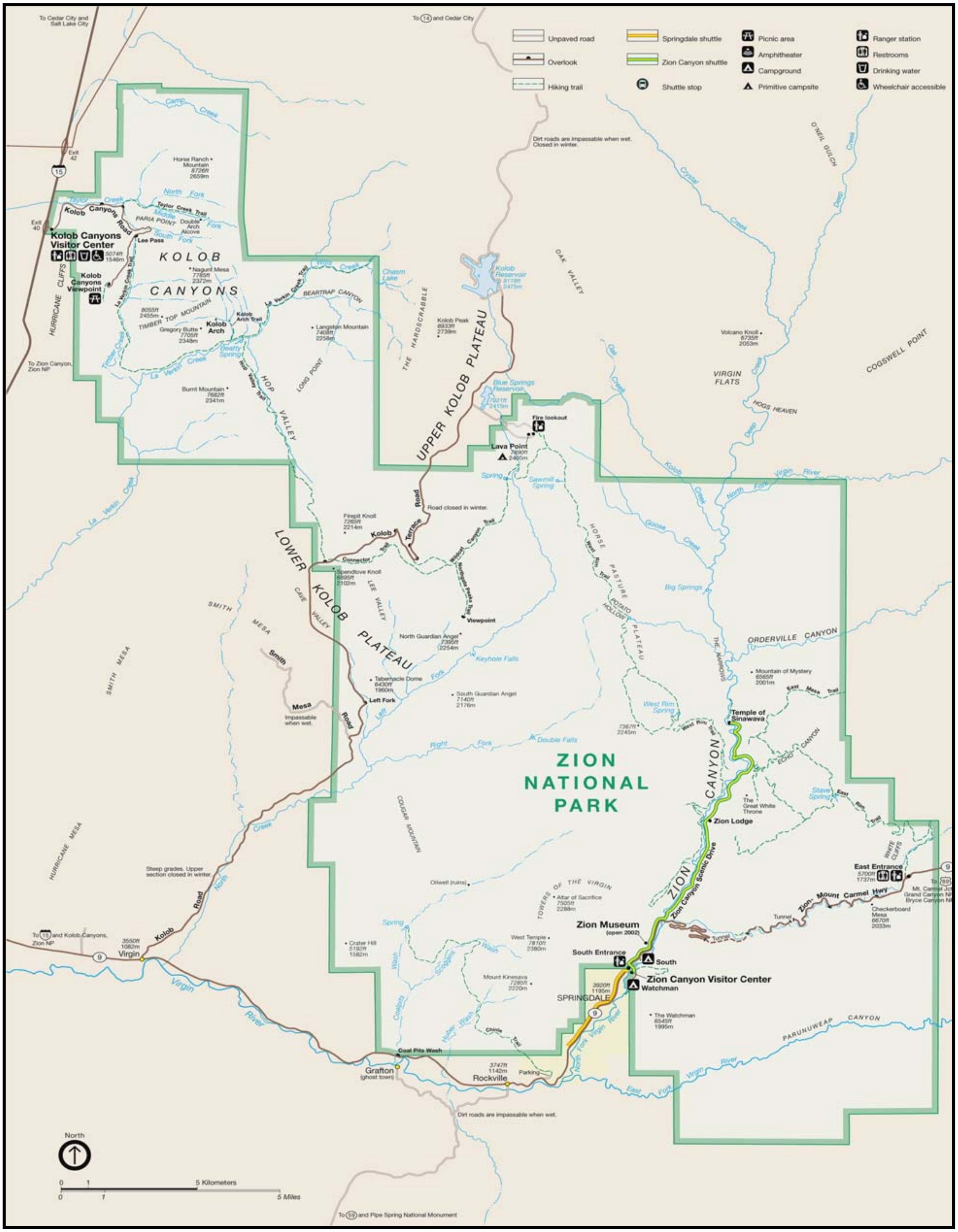


Figure 3. Zion National Park Map (1).
(obtained and modified from Zion National Park Website http://www.nps.gov/zion

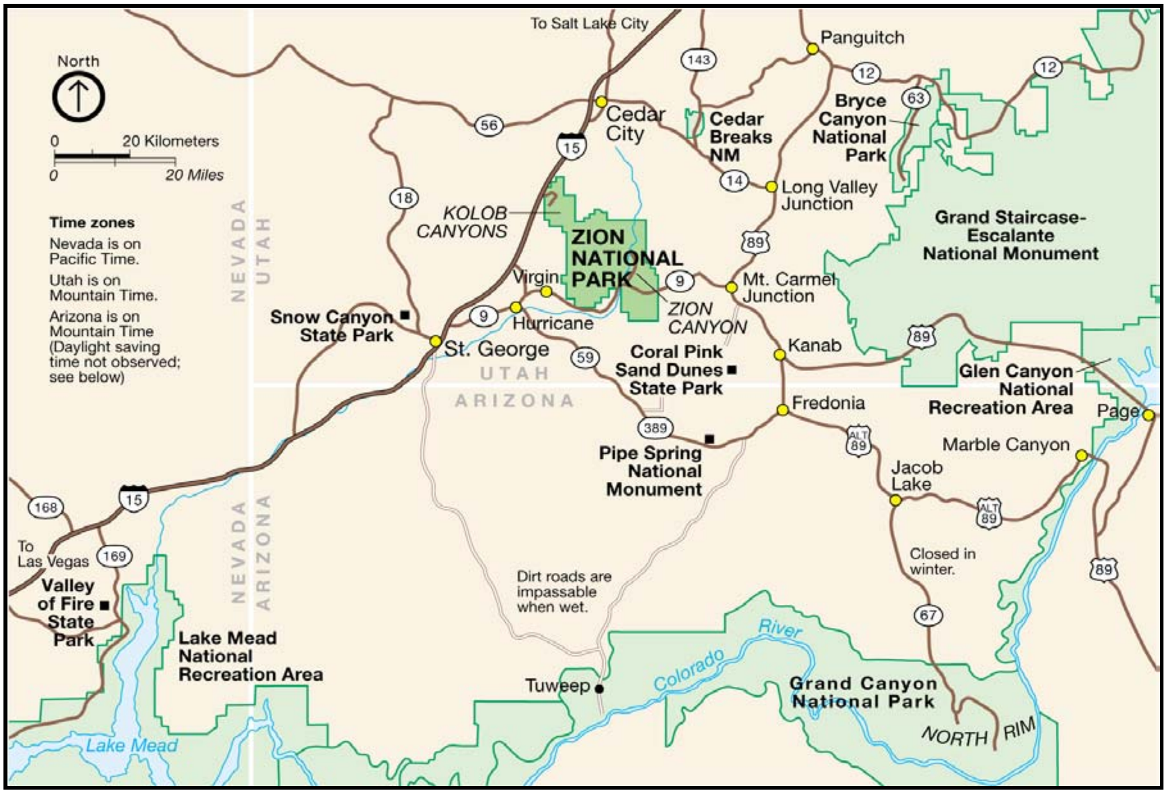


Figure 4. Zion National Park Map (2).
(obtained and modified from Zion National Park Website http://www.nps.gov/zion)

Hydrology

The Virgin River is one of the last relatively free flowing systems in the West and is the primary drainage for ZION. The North, Middle, and East Forks of the Virgin River all occur in ZION with the prominent North Fork forming Zion Canyon and the East Fork creating Parunuweap Canyon. Other important tributaries include Shunes, LaVerkin, Deep, Goose, and North Creeks (**Figure 3**).

Surface water in ZION comes primarily from runoff occurring within the watershed. Heavy rainfalls are common during the summer and can form flash floods in ZION's narrow canyons. Other sources of water in the Park include isolated seeps and springs. Within the porous Navajo sandstone formation, seeps produce waterfalls and support hanging garden vegetation.

Climate

ZION's semiarid climate can noticeably change both during the day, across elevations and between seasons. During the day temperatures can fluctuate over 30°F between mid-day heat and overnight cooling. Seasonal changes are also extreme with a majority of precipitation in the spring followed by hot, dry summers interrupted by prevalent monsoons or afternoon thunderstorms between late July and mid-September. Elevation creates heavy snowfalls in the winter for the northern portions of the Park.

As reported on ZION's website (http://www.nps.gov/zion), average yearly precipitation ranges from 14 inches in Zion Canyon to between 16 and 20 inches for the high country. Yearly temperatures for ZION vary from around 100°F highs in July to 30°F lows for December and January. Generally snowfall is very light in the lower elevations during the winter but can increase dramatically with elevation.

Vegetation

ZION's extreme range in elevation coupled with its topographic complexity creates a myriad of niches supporting a wide range of plants and plant ecosystems. During the course of this study we found that species could be grossly separated by life zones based on geography. The resulting pattern contains a range from low elevation desert shrubland communities with Mojave Desert elements, to mid-elevation shrublands and pinyon-juniper woodlands typical of the Colorado Plateau and Great Basin, to montane forests/oak-brush shrublands at higher elevations. Tucked in the many canyons are also important riparian, wetland, and unique environments such as hanging gardens.

At the lower elevations cryptobiotic soil covers much of ZION forming large crusts on very sandy soils. Vegetation here is generally sparse and low in stature due to lack of moisture. Semi-arid desert species such as blackbrush (*Coleogyne ramosissima*), Four-wing saltbush (*Atriplex canescens*), and pockets of Mesquite (*Prosopis glandulosa*) are common.

As you travel north in the park, frequency of riparian species becomes more pronounced along streams and rivers. Typical tree species include Fremont's cottonwood (*Populus fremontii*), boxelder (*Acer negundo*), and velvet ash (*Fraxinus velutina*). Coyote willow (*Salix exigua*) and seepwillow (*Baccharis emoryi*) are common shrubs. Narrow floodplains and sandy slopes next to waterways support a variety of shrubs and trees. These include predominately pinyon pines (*Pinus edulis, P. monophylla*) and one-seed juniper (*Juniperus osteosperma*), sand and big sagebrush (*Artemisia filifolia*, *A. tridentata*), and rabbitbrush (*Ericameria nauseosa*). Interspersed with these are pockets of grasses, mainly sand dropseed (*Sporobolus cryptandrus*) and Kentucky bluegrass (*Poa pratensis*).

Steep, rocky talus slopes form transitions between floodplains and Navajo sandstone formations throughout much of the Park. On these sites silver buffaloberry (*Shepherdia rotundifolia*) is prevalent along with live oak (*Quercus turbinella*) shrubs and pinyon and juniper trees. In the center of the Park and extending east are large areas of slickrock (Navajo sandstone) and its derived soils. Here, ponderosa pine (*Pinus ponderosa*) becomes more common along with opportunistic shrubs such as greenleaf manzanita (*Arctostaphylus patula*) and dwarf or littleleaf mountain mahogany (*Cercocarpus intricatus*). In mesic canyons, ravines, and north-facing benches, Douglas fir trees (*Pseudotsuga menziesii*) form lush stands.

As the Park rises in elevation to the north, semi-arid shrub dominance shifts to more mesic montane types. Ponderosa pine, aspen (*Populus tremuloides*) and white fir (*Abies concolor*) are common dominants. Tall shrubs consisting of Gambel oak (*Quercus gambelii*), common serviceberry (*Amelanchier alnifolia*), and bigtooth maple (*Acer grandidentatum*) are also usually present in great quantities.

Several problematic non-native and invasive plant species are found within the Park and are being actively controlled. These include salt cedar (*Tamarix ramosissima*), and Russian-olive (*Elaeagnus angustifolia*).

Historical agricultural or semi-natural lands are common on old homestead sites in and around ZION. Typically the disturbed sites occur on relatively flat land. Common species in these areas include a variety of non-native and native species especially suited to thrive on disturbed soils. These include cheatgrass (*Bromus tectorum*), wheatgrasses (*Agropyrum* spp.) and rabbitbrush. Also, ripgut brome (*Bromus rigidus*) is common on riparian benches and terraces, while smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis)* are common in mesic areas.

Wildlife

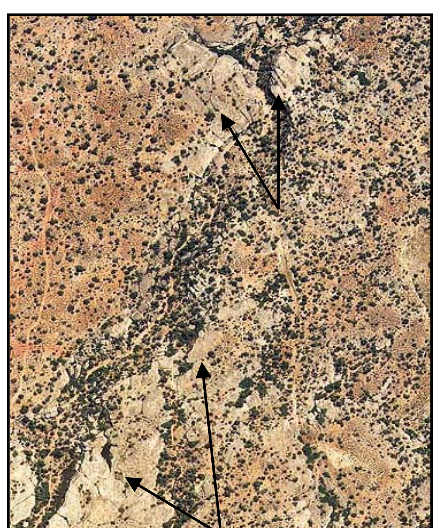
According to ZION's website (http://www.nps.gov/zion), the Park supports over 285 species of birds, 75 species of mammals, 32 reptiles and amphibians and 8 fish. Documented rare and endangered species include the peregrine falcon, Mexican spotted owl, southwest willow flycatcher, desert tortoise, and the endemic Zion snail. Mule deer, rock squirrels, lizards, and desert cottontail were some of the more common animals seen during this project.

Figure 5. Zion National Park Photo-interpretation Geologic Formation Reference.

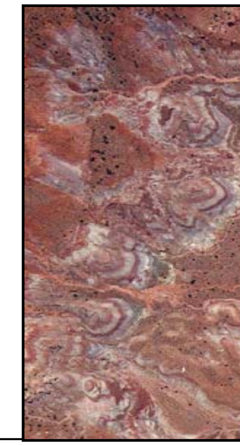
Oldest

Kaibab (White to Yellow) occurs only in two areas in the NW corner along the Hurricane Fault.

Moenkopi (Dark Red to Pink) occurs in SW and NW corner of Zion, low elevations.

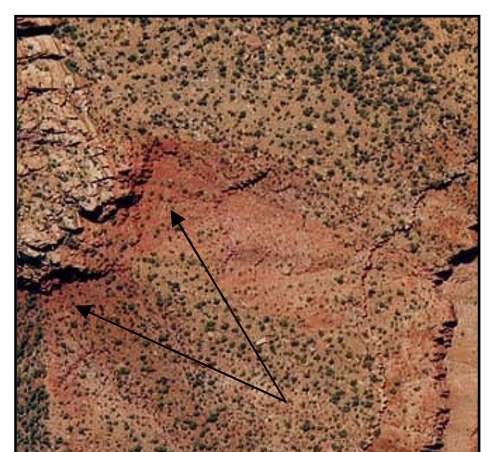


Chinle Shinarump (Light Tan to White) occurs in the low elevations. Forms cracked ledges.



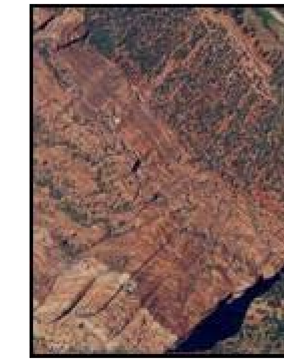
Chinle Petrified Forest (Gray, Purple, White, and Pink Bands) occurs in the low elevations.

Moenave (Red, Purple, or Pink) talus slopes, mainly in southern half of Zion.



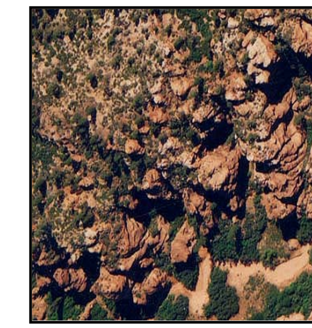
Kayenta (Red and Mauve) forms talus slopes at the base of the Navajo Sandstone.

Fractured



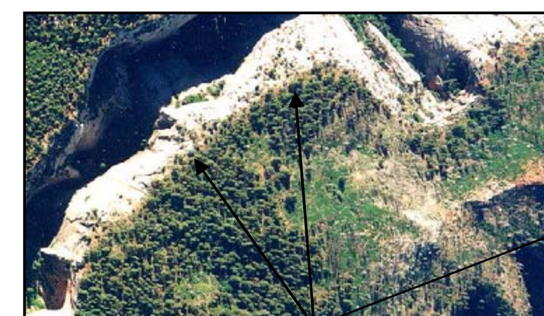
Brown

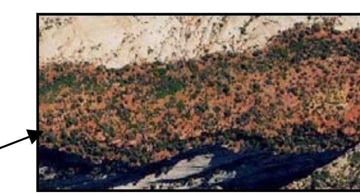
Pink and White



Fractured HooDoo's

Navajo (White, Pink, Brown) most extensive rock formation in Zion. Occurs as canyon walls and steep near-vertical cliffs.





Temple Cap (Orange and Red) cap rock directly above the Navajo formation at high altitudes.

Carmel (white, light gray, light tan) formation occurs at Zion in the highest elevations especially around Horse Ranch Mountain.

Youngest

Dakota (no photo) (white, gray) only occurs as a small area in the NW corner.

(All aerial photos were clipped from 1:12,000 scale true-color aerial photographs obtained from Horizon's

2. METHODS

Based on the overall project scope and the assignment of responsibilities, the project was divided into six major steps following the USGS flowchart (**Appendix A**):

1. Plan, gather data, and coordinate tasks;
2. Survey ZION to understand and sample the vegetation;
3. Classify vegetation using field data to NVCS standards and crosswalk to recognizable map units;
4. Acquire aerial photography and interpret using the classification scheme and crosswalk;
5. Transfer the interpreted data to a digital form;
6. Ground-truth and assess the accuracy of the final map product.

All protocols for this project as outlined in the following sections can be found in documents produced by The Nature Conservancy (1994a, 1994b, and 1994c) for the USGS-NPS Vegetation Mapping Program and found at this website: http://biology.usgs.gov/npsveg.

2.1 Planning, Data Gathering and Coordination

A scoping meeting was held in February 1999 and attended by RSGIS, NPS, NatureServe and CBI staff. The goals of this meeting were to (1) inform the Park staff and interested neighbors about the program, (2) learn about the Park's management issues and concerns, (3) review existing data, (4) develop a schedule and assign tasks, (5) get a commitment from the Park, (6) define possible cooperation with others, and (7) define a project boundary.

The scoping meeting was followed-up with a sampling design meeting held in April 1999 to further discuss the project boundary and define variables for a stratified random sampling approach.

Both meetings helped determine three important project decisions:

1. The project boundary was defined as 1-mile buffer or 'environs' extending around the Park. This was enlarged in the northwest corner to 2-miles to encompass important upstream watersheds (**Figure 1**).

2. New 1:12,000-scale true-color aerial photography would be required since the Park's previous sets were out-dated. Also, new 1-12,000 true-color orthophoto base maps would be acquired for the Park to help with the digital transfer.

3. Assignment of work responsibilities to the participants as follows:

BOR Responsibilities

- Help with overall project facilitation and coordination;
- Acquire new 1:12,000 scale true-color aerial photography and ortho-rectified imagery;
- Verify vegetation and land use/land cover signatures on the aerial photographs;
- Develop map units linked to the NVC;
- Provide NatureServe with information gleaned from the aerial photography regarding the distribution and characteristics of vegetation types within ZION;
- Interpret and delineate vegetation and land use types using aerial photographs;
- Transfer and automate interpreted data to a digital spatial database;
- Produce spatial coverages of plot and accuracy assessment site locations;
- Assist with the accuracy assessment;
- Provide a final report describing all aspects of the project;
- Provide a visual guide to the photo signatures of each map unit;
- Document FGDC-compliant metadata for all vegetation data.
- Create a CD-ROM with reports, metadata, guides, vegetation classification, plot data, spatial data, the vegetation database (map), graphics, and ground photos.

NPS Responsibilities

- Provide program oversight in conjunction with CBI;
- Supply RSGIS with the Park and Project boundary in digital format;
- Supply RSGIS with ancillary data;
- Assist with fieldwork and logistical considerations.

NatureServe Responsibilities

- Collect representative plot data for the vegetation classification and local NVC descriptions;
- Develop a vegetation classification for the study area based on the NVC using collected field data;
- Provide guidance regarding the ecology and floristic composition of the vegetation types;
- Provide global and park-specific vegetation descriptions
and keys to the vegetation;
- Collect accuracy assessment ground data to be used for analysis of the thematic accuracy of the GIS vegetation layer.

Work began by gathering copies of maps, soil surveys, reports, and other documents describing the Park and its environmental setting. ZION provided species lists, National Wetland Inventory data, previous vegetation maps, geology maps, and other relevant information. NatureServe provided a list of potential plant associations.

At this time, we also evaluated existing plot data from previous studies at ZION as to its usefulness in the vegetation classification and mapping. Of particular consideration was the plot data and study methodology from Harper (1980) used in an earlier ZION vegetation map. Upon review, all previous data for ZION, including Harper's, were judged as being useful only for gross classification and cursory verification of the vegetation. Reasons for rejecting this data included questionable positional accuracy of the plots and a lack of detail in reporting species and their cover.

2.2 Field Survey

Overall, the field methods used by NatureServe for developing the classification and conducting the accuracy assessment at ZION followed the methodology outlined by the USGS-BRD/NPS Vegetation Mapping Program (Grossman *et al.* 1994). A summary of the methodology, as it was applied at ZION, is presented below.

As the 1999 field season approached, preparations were made by NatureServe for collecting sample plot data at ZION. This involved creating a preliminary list of vegetation associations and alliances from the NVC in February 1999. We agreed upon a total of 74 associations (68 existing NVC and 6 proposed by Zion staff) for the preliminary classification in May 1999 after several meetings. The preliminary classification was initially used to set targets for data collection. Each association was targeted for 3-5 plots. Associations that were relatively well known and described from other areas were given fewer plots, and those that were thought to be new to ZION or known from elsewhere, but not well characterized were given more. The preliminary classification was a working document that was refined as new information became available from the vegetation sampling.

Sampling Design: Stratified Random Gradsect

Our ultimate goal at ZION was to obtain a thorough description for the range of plant communities, both the common/extensive and the rare/unique (Austin and Heyligers 1991). To this end we felt that an unbiased census of all the vegetation (*i.e.* a complete enumeration of the population) would not be achievable or practical for such a large, remote Park. As a result, to cost-effectively capture the full spectrum of vegetation we felt it necessary to optimally locate sampling plots using "Gradsect Sampling" (GRADient-directed tranSECTs) (Gillison and Brewer 1985).

Gradsects are a survey method that addresses 1) the need for representative sampling based on environmental stratification, 2) the need for a compromise between statistical sampling, practical logistical problems, and costs, and 3) the value of replicated and randomized sampling (Austin and Heyligers 1991, Gillison and Brewer 1985). We assumed that a modified Gradsect methodology would allow field crews to visit the full spectrum of physical environments and thus most of the vegetation types.

For ZION, we decided that a spatial-historical model coupled to a 30-meter digital elevation model (DEM) of the Park would be more predictive of vegetative diversity and more efficient than a linear transect approach. A working group of USGS, NPS, and NatureServe ecologists/botanists familiar with the region selected the model's driving variables; those thought to influence vegetation response. During this process, practical constraints were also considered including the lack of time and money to develop new digital data layers.

For ZION's modified gradsect, geology, solar insolation, hydrology and fire history were chosen (elevation was omitted except for volcanic substrates because of its close correlation to the sedimentary geologic layers that characterize the Park) as the key abiotic factors (**Table 1**). We then split each gradsect variable into logical classes to best reflect the vegetation distribution and created digital map layers using ArcView GIS (**Table 1**). These GIS layers were then added together to generate a map coverage of all combinations occurring in ZION, with each unique combination representing a Biophysical Unit (BPU).

At ZION there were 70 BPU types within the Park that formed a mosaic of 18,000 polygons. We selected a subset of these BPUs using a cost-surface analysis, which favored polygons that were more accessible, of adequate size, and spatially dispersed. This resulted in 2-3 polygons of each type for a total of 170 polygons selected for possible sampling during the initial field season. At Zion, polygons averaged from 1-10 ha in size, although the overall range was 0.18-110 ha. This cost-surface process for selecting sampling locations was especially important for ZION, due to access difficulties caused by the steep, vertical nature of the Park.

For more detailed information on the Zion National Park Analysis - Sample Site Selection Methodology see **Appendix B**.

Table 1. Environmental variables and classes used in the modified Gradsect analysis for ZION. The combination of variable classes is called a Biophysical Unit or BPU. Example: *upland, unburned, partial shade, Dakota formation* (**2235**).

HYDROLOGY	FIRE HISTORY	SOLAR INSOLATION	GEOLOGY
1000-Hydric	100-Burned	10-Full Shade	1-Alluvium
2000-Uplands	200-Unburned	20-Partial Sun	2-Carmel
		30-Partial Shade	3-Chinle/Moenkopi/Kaibab
		40-Full Sun	4-Slide/Kayenta/Moemave
			5-Dakota
			6-Navajo/Temple Cap
			7-Volcanics 3600-5300 ft.
			8-Volcanics 5301-7000 ft.
			9-Volcanics 7001-Summit

Data Collection: Relevé Plots

The BPU polygons selected in the sampling design only provided guidance to possible sampling locations for the field crews and were not the targets. Rather, it was the vegetation found on and in the vicinity of a particular BPU polygon that was actually sampled. Once they reached a selected BPU location, field crew(s) located vegetation plots in areas that were relatively homogeneous and representative of the vegetation to be sampled. Field crews were instructed to avoid areas where vegetation was transitional between types, such as ecotones.

Plot locations were recorded from plot centers using Rockwell **PLGR** (Precision Light-Weight GPS Receiver) GPS units provided by the Park. UTM X-Y coordinates and elevation were recorded both manually on the plot forms and stored as waypoints in the GPS unit. All readings were downloaded from the units, including the accuracy estimates, and transferred to an Access database. Average error ranged between ±5-10 meters with more error associated in canyons and dense canopy.

We recorded all plot information on a standard plot form (**Appendix D**). Environmental information recorded included: elevation, slope, aspect, landform, topographic position, soil texture and drainage, surficial geology, hydrologic (flooding) regime and evidence of disturbance or wildlife use. Pick lists of environmental variables were provided to help standardize naming (**Appendix D**). Vegetation structure and species composition were sampled using plots that varied in size depending on the dominant physiognomy of the vegetation. Forest, woodland and shrubland plots were 400 m^2, while dwarf-shrubland and herbaceous vegetation plots were 100 m^2. Plot shapes were typically square or circular, but were modified to best represent the vegetation, e.g., narrow, linear rectangles for riparian vegetation. Plot dimensions were recorded.

Within each plot, we visually divided the vegetation into strata, and the height and canopy cover of vegetation was estimated for each stratum. Physiognomic class, leaf phenology, and type of dominant stratum were recorded. The species of each stratum were then listed and percent canopy cover estimated using a twelve-point cover scale (<1%, 1-5%, >5-15% …) (Daubenmire 1959). Additional species within the vegetation unit that occurred outside of sampled plots were listed separately. Non-vascular species cover was summed as either lichen or moss depending on life-form. No attempt was made to identify individual non-vascular plants. The plant species lists may not be exhaustive for all plots but they do include all major and most minor species. Species that were not identifiable in the field were collected for later identification. Species were recorded by scientific epithet familiar to researchers and synonymized with the nomenclature of Kartesz (1999).

For plots with trees, the diameter at breast height (DBH) was measured and recorded for trees with DBH greater than 10 cm. Trees with stems 5-10 cm DBH were tallied. Multi-stemmed trees such as *Quercus gambelii* were also measured and recorded as such. Finally, a provisional vegetation type was assigned to the plot. Please see **Appendix C** for more information on the plot data collection.

Plot Data Collection at ZION

Data Collection: Fire Specific Data

At Zion, fire-modeling data was also collected in tandem at many of the vegetation plots. In 1999, Zion fire program personnel accompanied the vegetation field crew to collect fire-modeling data and in 2000 a member of the field crew was trained to collect fire data. Data such as height to live crown, fuel types and fuel amount were collected in each plot.

Data Collection: Plots

Our field sampling goals were to have 3-5 plots per plant association with less well-understood and more diverse associations receiving more sampling. All plots were to be spread across ZION to capture diversity within each association. Plot sampling was conducted during the summer of 1999 and spring-summer of 2000. The 1999 sampling period was relatively short, occurring from July 21 – August 27 after NatureServe contracted a 2-person field crew. This effort resulted in **91** plots located in areas that were relatively accessible.

The 2000 field season consisted of 3 sampling periods. The first was a short early spring reconnaissance trip conducted by BOR (April 1-4) to help jump-start the data collection and increase the number of sample plots. Due to the early timing, we sampled mostly in low elevation communities producing **16** plots. Following this effort, the main field season ran from May 18 - August 17 using one, 2-person field crew contracted by NatureServe. This effort resulted in **161** plots. Many of the plots collected at this time were sampled in less accessible areas.

Subsequent evaluation of the distribution of the plots by BOR and ZION revealed large remote areas devoid of data (**Figures 6 and 7**). In order to provide better coverage we ran a final period from August 21-24 concentrating on backcountry and isolated mesas. A quick feasibility study using The Bureau of Reclamation's helicopter was conducted by BOR and presented to ZION. ZION approved the use of the helicopter and was instrumental in obtaining the necessary permits, finding volunteers and providing safety personnel (*i.e* heli-techs).

Using four to five 2-person field crews, including Utah Flora (1993) authors Dr. Stanley Welsh and Dr. Duane Atwood, we were able to access and sample 31 relatively inaccessible and pristine areas of Zion (**Figure 6**). The four days of helicopter-assisted work (24 flight hours) resulted in **78** vegetation plots and 9 more general, observation points (See **Appendix G** for more details). Due to "one-shot" accessibility some of the plots were held back and used as accuracy assessment points.

Shuttling of field crews using the BOR Helicopter at ZION.

2.3 Plot Data Management and Classification Analysis

Upon completion of the field work, all information from the 346 plots at ZION were entered into the NPS PLOTS database (TNC 1997), a MS Access-derived program. PLOTS was developed expressly for the NPS vegetation and mapping program so that the electronic data entry fields exactly mirror the standard field forms (see **Appendix D**). This was facilitated by assigning each plant species an unique, standardized code and name based on the PLANTS database developed by National Resources Conservation Service in cooperation with the Biota of North America Program (http://plants.usda.gov). After data entry, we checked for any errors such as duplicate entries or erroneously selected plant names (from database pick-lists), based on distribution and Park species lists. Unknown species, especially those with high cover, were resolved, as were other taxonomic issues such as grouping some subspecies and varieties judged to be ecologically similar.

By manipulating these data, NatureServe was able to sort and classify the vegetation associations as they related to the NVC. In some cases obvious qualitative sorting into groups based on vegetation structure and composition allowed for simple assignment to existing associations. However, most of the plots needed thorough quantitative analysis using ordination and classification programs.

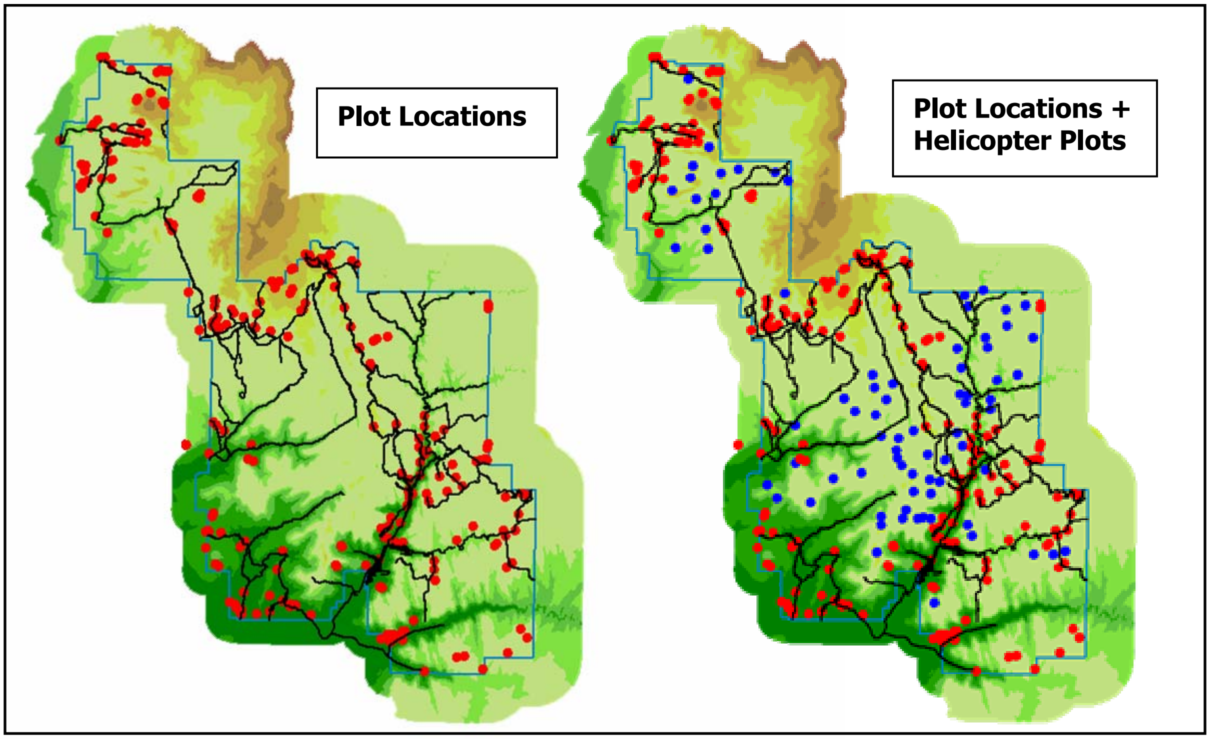


Figure 6. Comparison of plot sample distribution before and after the use of the BOR helicopter. (Red dots indicate plot locations, blue dots indicate helicopter-assisted plot locations, and lines are major roads and trails. Please note that some of the plots were held back from the photo-interpreters and used as accuracy assessment points.)

Quantitative analysis involved preparing the species and environmental data by formatting them for use in the analytical programs. For species data this meant grouping species into species-by-strata cover value combinations to address species occurring in multiple strata. Environmental data were also manipulated to improve analysis by grouping both landform/geology and aspect classes into fewer, more ecological-meaningful categories (*e.g.* sunny/hot aspects E-NW and shady/cool aspects NNW-NE).

After formatting, the data were analyzed in a series of runs in PC-ORD Multivariate Analysis software package (McCune and Mefford 1997). The process involved partitioning the larger data set into smaller sets until sufficient resolution was achieved to classify stands into an existing NVC association or develop a new type. Specifically, this was accomplished by using several multivariate procedures, including Detrended Correspondence Analysis, or DCA (Hill and Gauch 1980) and Two-Way Indicator Species Analysis, or TWINSPAN (Hill 1979). CANOCO was also used to perform (partial) (detrended) (canonical) correspondence analysis (Ter Braak 1987-1992), relating species and samples to environmental variables.

In short, we used DCA to ordinate both species and samples simultaneously based on floristic patterns. These ordinations were then reviewed and assessed for perceived environmental gradients (*e.g.* moisture gradients, aspect, soil textures, soil depth, etc.). (See **Figure 8a**, for an example of a DCA ordination expressing a moisture gradient). To complement the ordinations of DCA, we used TWINSPAN to successively divide the plots into groups that were similar in species composition. This provided us with a table showing plots ordered by indicator species.

During analysis, small groups of plots very dissimilar to all the others (*i.e.* outliers) were removed in an iterative fashion from the larger data set before it could be partitioned into major groups for further analysis. Most of these outlier plots corresponded to existing NVC associations, and included wetlands, a lowland grassland, dry shrublands, a riparian shrubland, and wet meadows. The major remaining groups were pinyon and juniper woodlands and

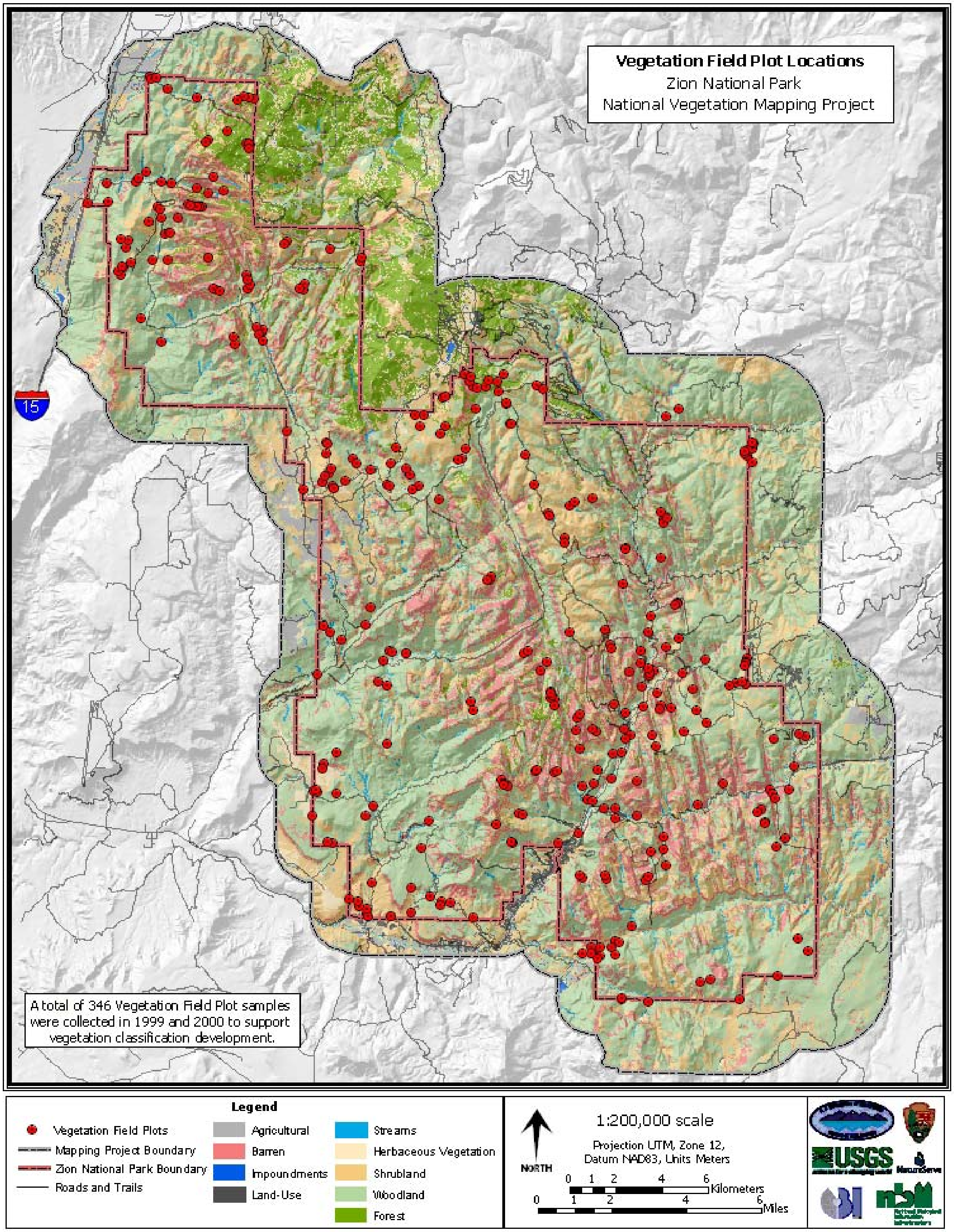


Figure 7. Location of all vegetation plots collected at ZION.

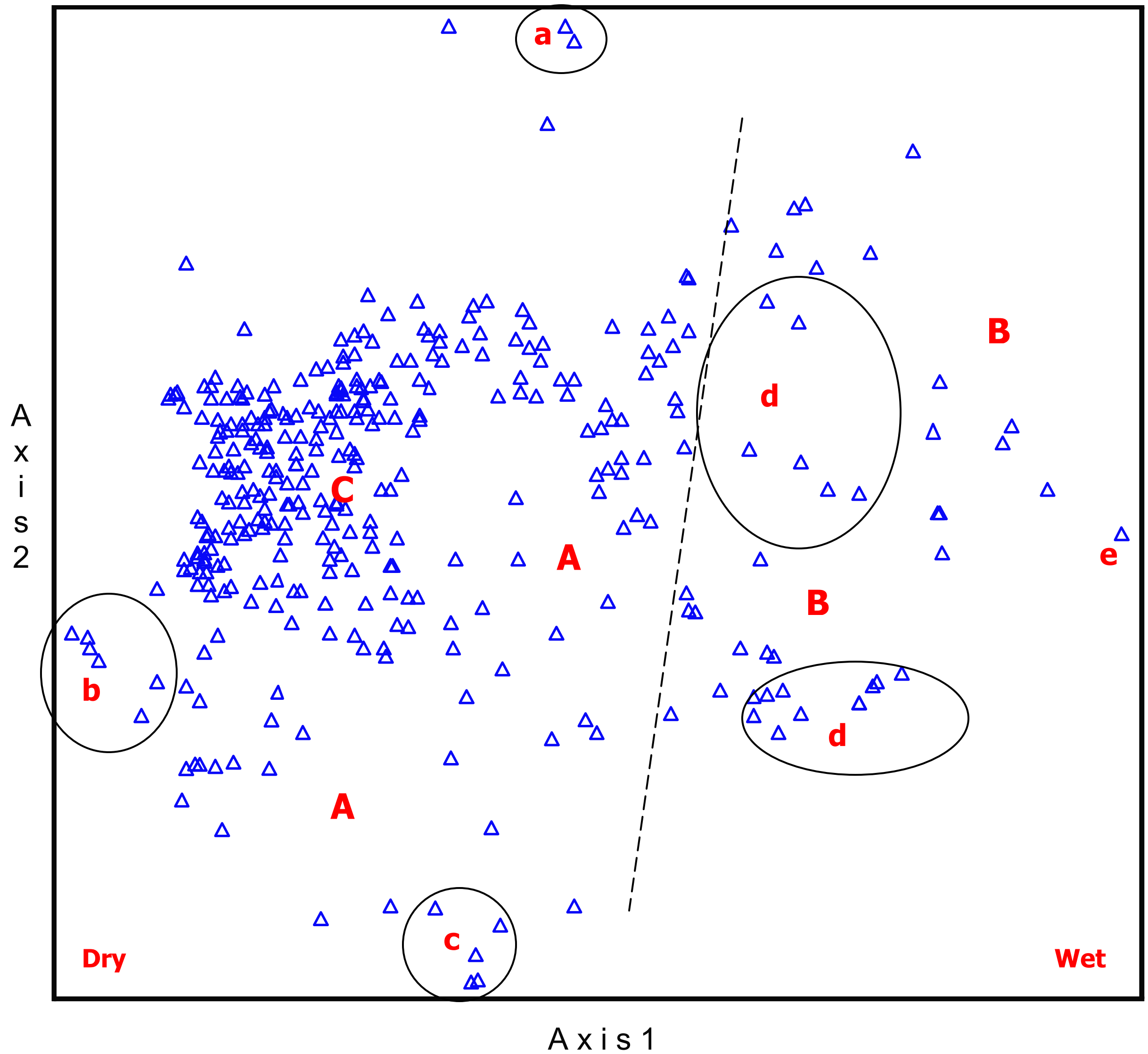


Figure 8a. DCA ordination of complete Zion dataset (346 plots).

This plot shows the distribution of plots on a dry to wet environmental gradient (Axis 1). Note how dry shrubland and grassland plots (A) and wet meadow, riparian shrubland and forest plots (B) were partitioned (dashed line) from each other and from a dense mass of woodland and montane shrubland plots (C). Distinctive groups include smooth brome grassland (a), blackbrush shrublands (b), sand sagebrush shrublands (c), Fremont cottonwood riparian forests (d), and a sedge wetland (e).

montane vegetation. We further divided the montane vegetation into montane shrublands, ponderosa pine, other montane conifers, aspen, and riparian forests and woodlands. **Figures 8a-d** demonstrate this process of identifying outlier plots and successively partitioning the datasets into distinctive, smaller groups of plots. These groups were then analyzed separately and compared with the NVC (Grossman *et al.* 1998). Throughout, care was taken not to over-emphasize local variations found at Zion compared to more extensive information compiled at the regional level. Nevertheless, several type in the NVC were revised based on these analyses and new associations were identified from ZION's data.

A complete list of NVC plant associations for ZION was created (**Table 3**) and sent to Julie Thompson, our field crew leader. Julie drafted local descriptions for each association based on the data contained in the plots and her

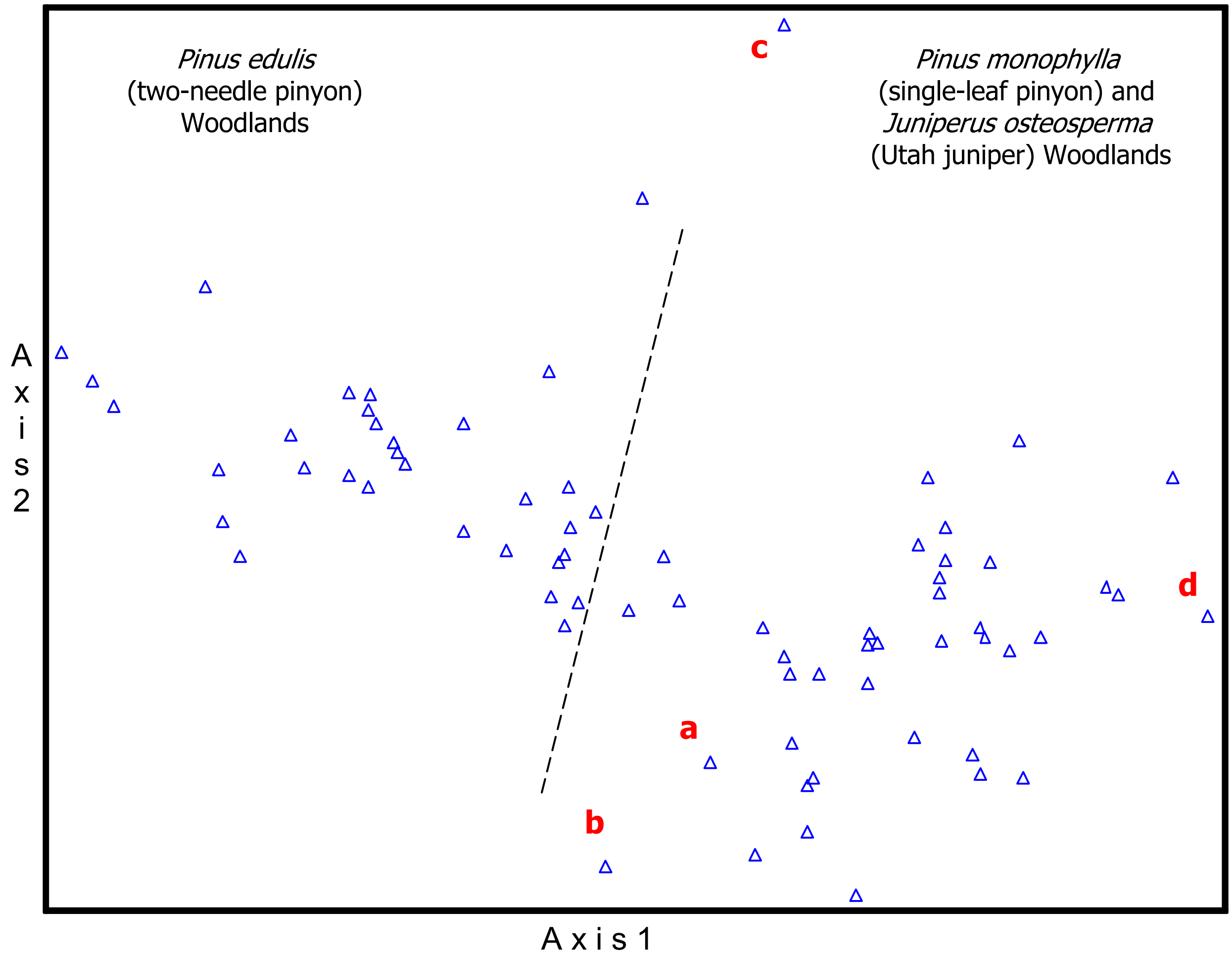


Figure 8b. DCA ordination of plots preliminarily in the Zion pinyon-juniper woodland dataset (73 plots).

This figure shows the distribution of *Pinus edulis* (two-needle pinyon) and *Pinus monophylla* (single-leaf pinyon) woodlands separated by a dashed line. *Juniperus osteosperma* and *Pinus monophylla* woodlands typically occur at lower elevations and on southern exposures, whereas *Pinus edulis* woodlands occur at higher elevations often with montane shrubs. A *Pinus edulis - Juniperus osteosperma* Woodland stand (a) was grouped with *Pinus monophylla* woodlands perhaps because of similar understorys. Three outlier plots (b), (c) and (d) were later classified as *Symphoricarpos longiflorus* shrubland, *Quercus gambelii / Amelanchier utahensis* shrubland and *Pleuraphis jamesii* grassland, respectively.

experience. The final ZION classification, containing both the global and local elements, was then sent to ZION for review and their subsequent approval (**Appendix F**).

Once the associations were finalized, a dichotomous key was developed for use during the Accuracy Assessment (**Appendix E**). Finally we cross-walked or linked the final associations to map classes (**see Section 3.3**) for use in the photo-interpretation and mapping portions of the project.

2.4 Aerial Photography and Orthophotos

Mapping Challenges

Experience told us that ZION's steep canyons would create shadow and scale distortion on the aerial photography. Specifically, we expected the canyon walls to block light from reaching canyon bottoms resulting in large shadows obscuring vegetation and hindering photo-interpretation (**Figure 9a**). This would be compounded by the extreme change in elevation (greater than 2000 feet in some cases) from

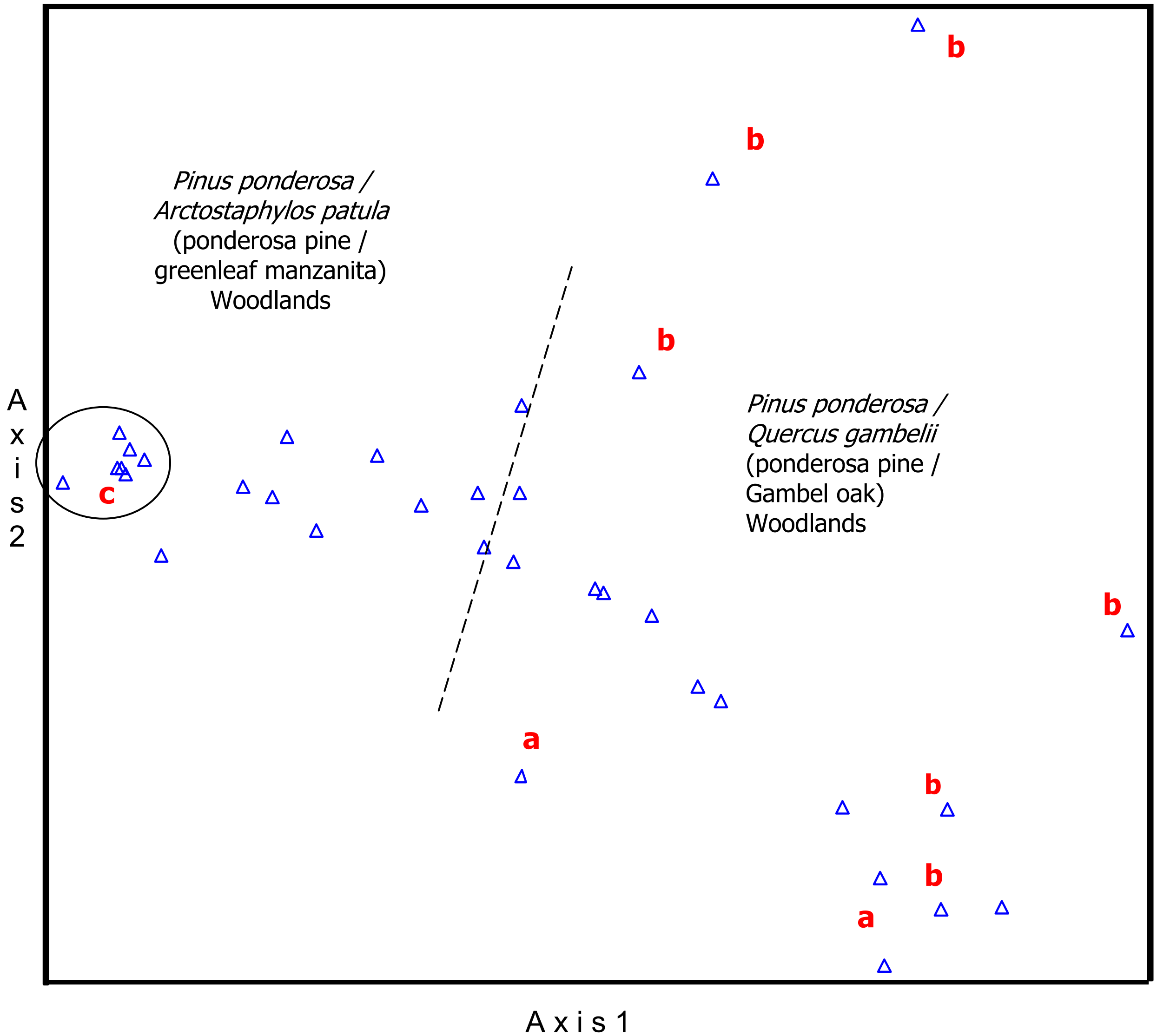


Figure 8c. DCA ordination of a subset of Zion plots preliminarily classified as Pinus ponderosa (ponderosa pine) woodlands (35 plots).

This figure shows the distribution of two common associations separated by a dashed line and plots later classified as other *Pinus ponderosa* woodlands (a); *Psuedotsuga menziesii, Abies concolor or Quercus gambelii* woodlands (b), or *Arctostaphylos patula* shrublands with scattered *Pinus ponderosa* trees.

the canyon floor to the mesa tops (**Figure 9b**). Photos taken at a steady, mean elevation will thus vary greatly in scale from the highest point to the lowest point on the landscape. To help overcome these obstacles we implemented a new approach to photo interpretation that deviated from past projects. This approach hinged on acquiring multiple sets of aerial photography across many flightlines and using these to produce new digital orthophoto base maps.

Aerial Photography

Horizons, Inc. (Rapid City, SD) flew true-color aerial photography for ZION at scales of 1:12,000 and 1:40,000 on June 22 and 23, 1999 (**Figure 9a**). We chose true-color film because of its ability to penetrate shadows allowing shapes of vegetation to be discerned through dim light (**Figure 9b**). At the 1:40,000 scale, Horizon's exposed approximately 135 frames along 16 flightlines to cover the project area.

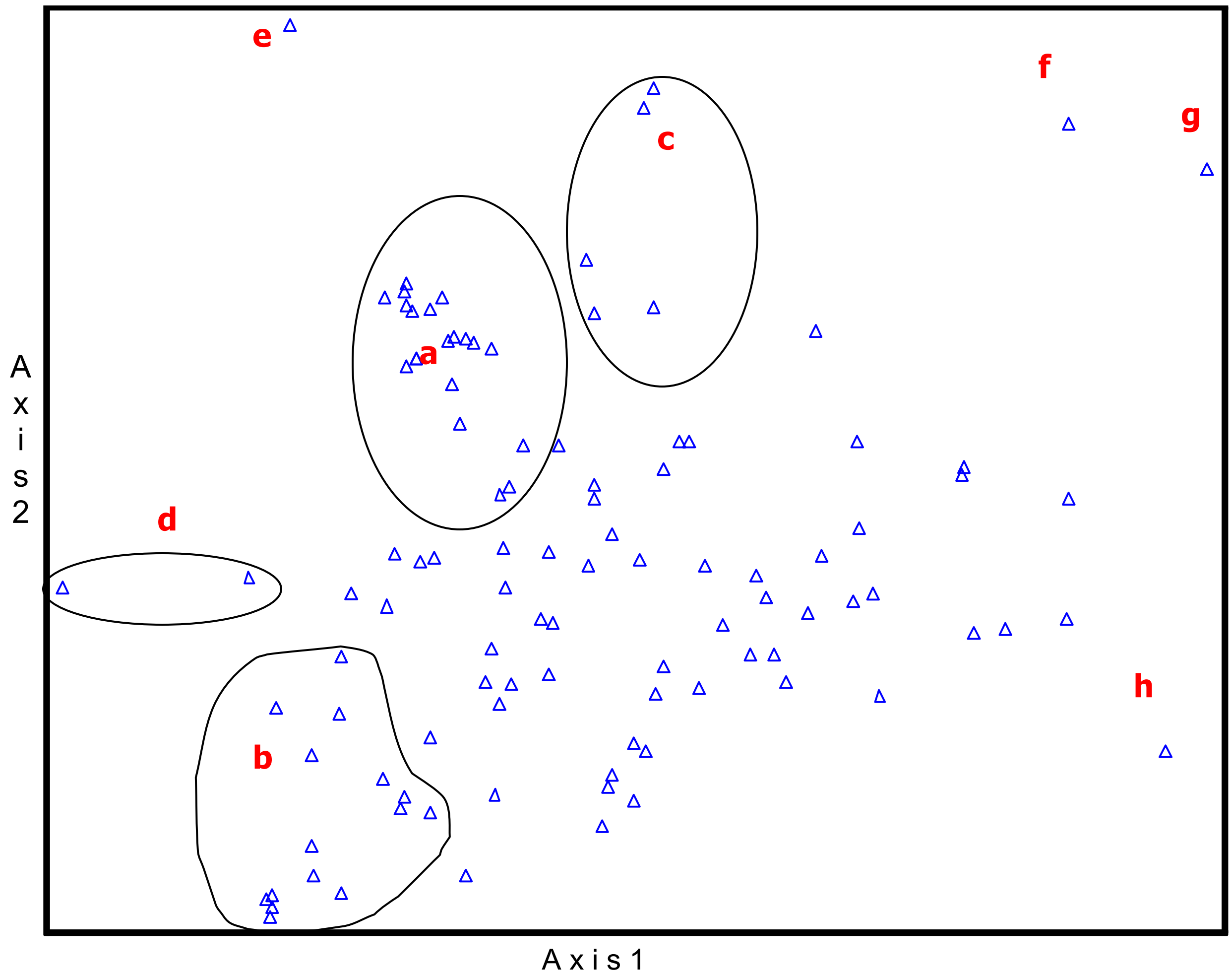


Figure 8d. DCA ordination of plots preliminarily classified as Zion Montane shrublands (103 plots).

This figure shows the distribution of four groups of plots: *Arctostaphylos patula* shrublands (a), *Quercus gambelii* mixed shrublands (b), *Artemisia nova* dwarf shrublands (c), and *Artemisia tridentata ssp. vaseyana / Hesperostipa comata* shrublands (d). Outlier plots include *Quercus gambelii / Juniperus osteosperma* shrubland (e), *Poa pratensis* semi-natural grassland (f), *Artemisia tridentata* ssp. *tridentata / Pascopyrum*

At the larger scale of 1:12,000, it took over 1150 frames along 35 flightlines (**Figure 10**) to cover the same area. This included additional overhead flights taken directly following the direction of ZION's larger canyons to minimize sun angle (**Figure 9c**). Frame overlap on both sets of photography was between 50% and 60% along the flight lines and 20% to 30% between the flight lines.

1:12,000 True Color Orthophotos

In addition to 9x9 inch prints of the 1:12,000-scale aerial photography, we also had Horizons Inc. develop new orthophotography from the 1:40,000 scale aerial photos. This was delivered to us as both digital files and hardcopy plots. Getting new orthophotos was based on a cost analysis comparing the price of the processing versus the amount of time saved in the digital transfer stage. Basically, we determined that the orthophotos would save the project more money in the long run by dramatically reducing digitizing labor costs.

Horizon's created the orthophotos by removing the distortion caused by the tilting of the camera and scale variation in the terrain. This was achieved by digitally scanning the photos and creating a mosaic. The digital mosaic was then magnified to 1:12,000 and rectified or corrected through a mathematical process that warps and stretches the image between known control points. For ZION, control points were gleaned from 10-meter and 30-meter digital elevation models (DEMs). The end result was a true-color digital image (1-meter pixels) that had an uniform scale of 1:12,000 (**Title Page; Figure 11**). Further, since the mosaic was created by cropping only the best portions of the aerial photos, much of the shadows were removed. Unlike aerial photos, the orthophotos made it possible to measure directly on them allowing UTM XY coordinates and other measurements to be accurately located.

2.5 Photo-interpretation and Map Units

Photo-interpretation

To take advantage of reduction in distortion and shadow we interpreted directly from paper copies of the orthophotos. This deviated from other vegetation mapping efforts where the actual 9x9 inch aerial photos were interpreted. However, at ZION we felt that photo interpretation of the vegetation could be conducted far more efficiently and as accurately using the aerial photographs only in an ancillary role. This was accomplished by interpreting in two stages. The preliminary interpretation identified patches of readily identifiable homogenous vegetation (areas with similar tone, texture, color, and landscape position) on the orthophotos. We then used the 9x9 inch aerial photos in stereo-magnification in a second interpretation to map the final NVC-derived map units (detailed).

For both levels of interpretation, we split the orthophoto into 27, 1:12,000 scale sheets and printed them on photographic paper with a 1,000 meter UTM grid. These were then covered with translucent (semi-frosted) Mylar, fastened together, and backlit on a light table. All UTM grid points were marked on the overlays and the initial polygons were delineated using a 0.5 mm lead pencil.

Once all the obvious vegetation and land-use classes were delineated we proceeded into the second stage. In this round of interpretation we used a stereoscope to help recognize complex photo signatures and three-dimensional features on the 9X9 aerial photos.

Additional Mylay overlays on each aerial photo allowed us to make notes and delineate polygons. We then manually transferred these to the orthophotos (**Figure 11**). Finally, in order to insure completeness and accuracy, digital transfer specialists reviewed all of the interpreted orthophotos for consistency and recommended changes where necessary.

Map Units

The map units delineated on the orthophotos were derived from the NVC classification as constrained by the limitations of the photography. We combined the preliminary NVC classification with the aerial photo signatures to determine how many plant associations could be recognized on the photos. In most instances, one NVC association corresponded to one map unit. However, sometimes a plant association could not be recognized consistently on the photos or we could see more detail than was recognized by the classification. These problems were overcome by using two separate but related classifications: 1) the NVC for the plot data and 2) map units for the GIS database. The two were related or "crosswalked" by noting when plant associations were lumped into a single map unit or where when associations were split into multiple map units (**See Section 3.3**).

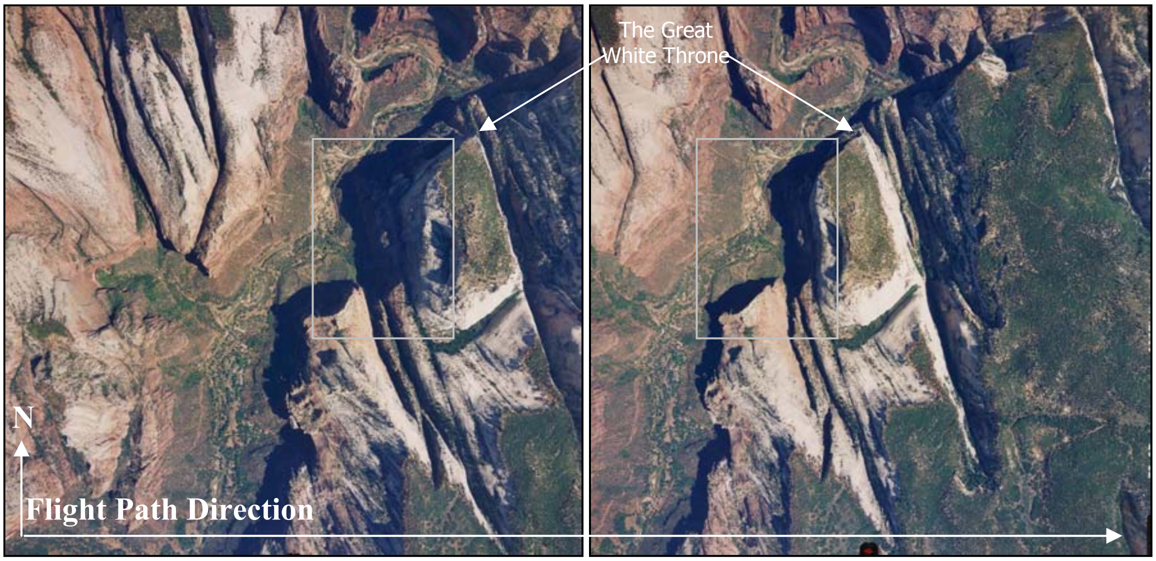


Figure 9a. Examples of 1:12,000-scale aerial photographs from the ZION Vegetation Mapping Project. (Examples are a stereo-pair of The Great White Throne. Notice the shadows and distortion in outlined area and its change between photos. -Examples are not printed to scale.)

Figure 9b. An enlargement of the Great White Throne at ZION showing discernable features in the shadow using true color photography.

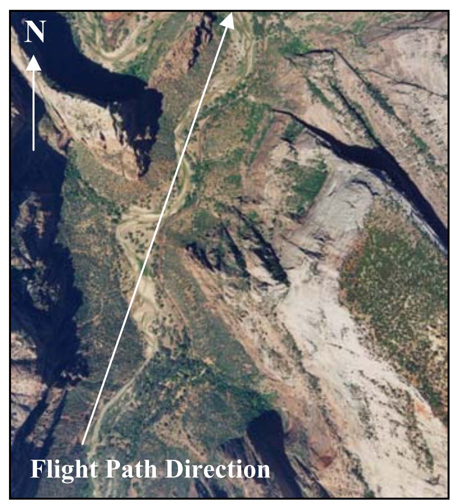


Figure 9c. An enlargement of the Great White Throne at ZION taken from a flight line that followed Zion Canyon, effectively eliminating any shadow.

We created map units for land-use types based on the system developed by Anderson (1976). This includes unvegetated lands not included in the NVC, such as roads, facilities, and agricultural fields. A third class of map units, "Park Specials", was defined especially for ZION to cover types that were easily mapped, wanted by the Park, but not included in either the NVC or Anderson. This included things like tinajas. A final list of the map units appears in **Table 3**.

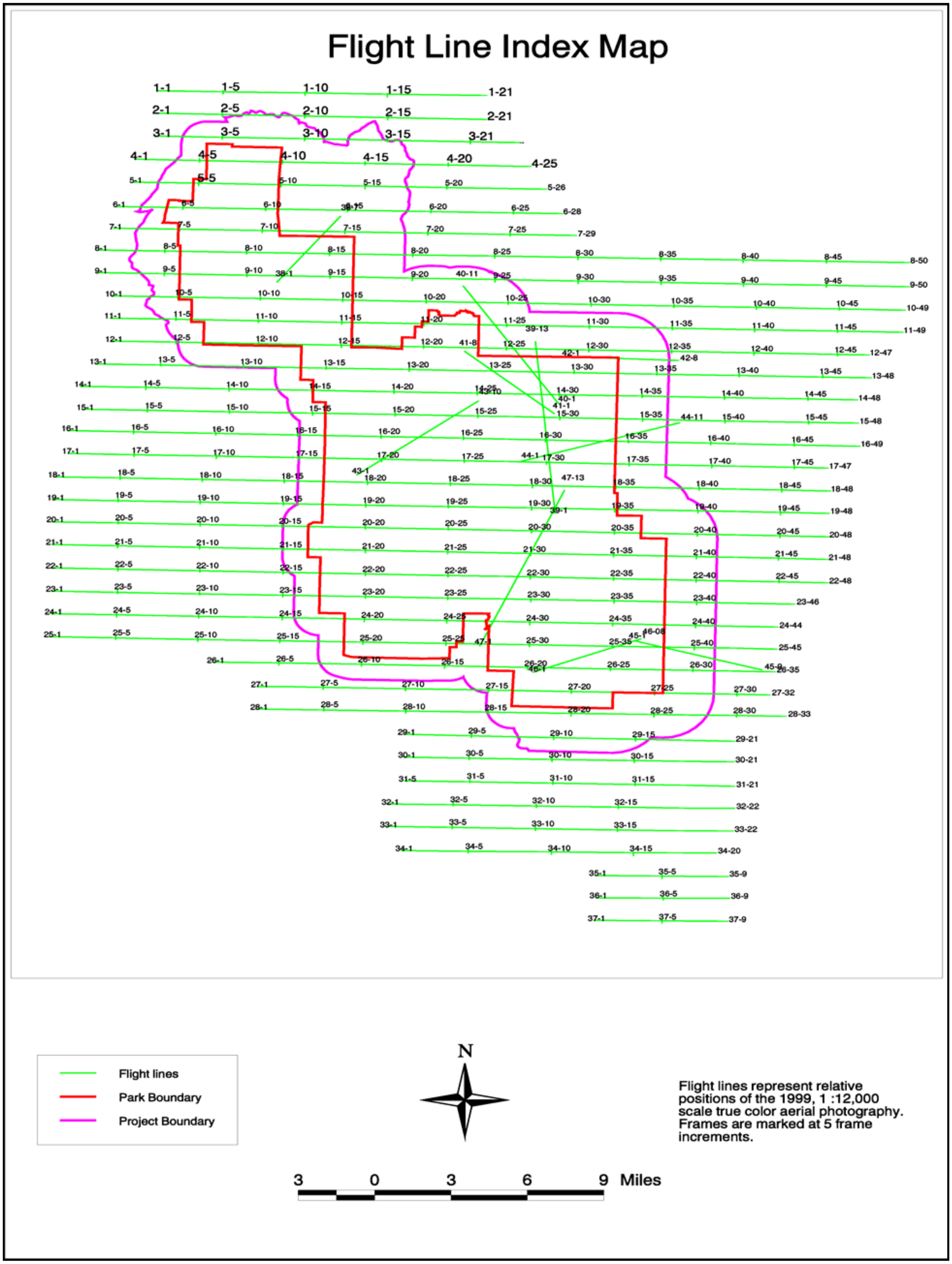


Figure 10. 1:12,000-scale Flightline Index Map for ZION.
(Note the extra, diagonal flightlines flown along the main canyons to help reduce shadows.)

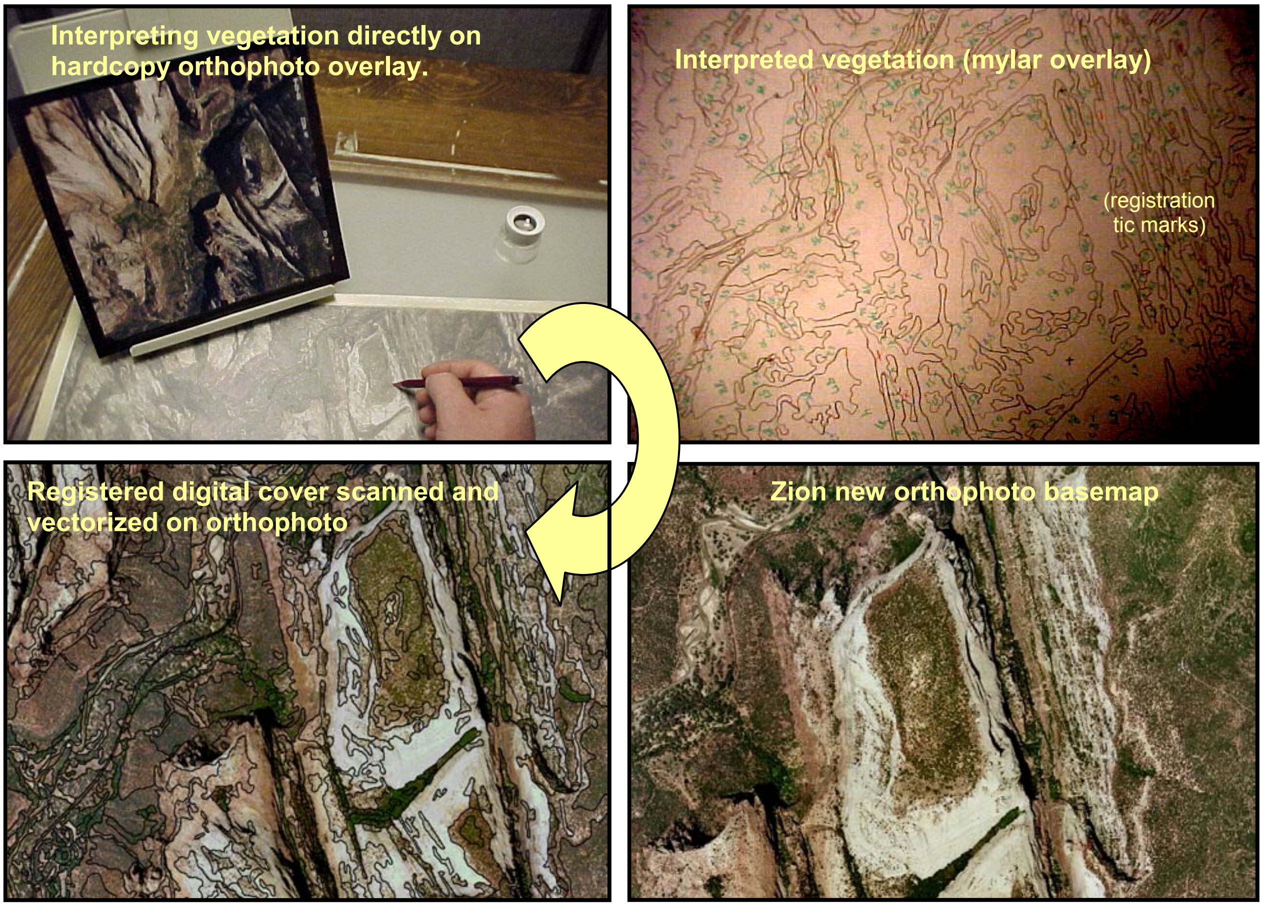


Figure 11. Color Orthophoto and USGS Quadrangle Reference Map for ZION.
[Note the lack of shadow and distortion on the orthophoto for the Great White Throne at ZION.]

2.6 Digital Transfer

The transfer process for ZION involved taking the interpreted line work and rendering it into a comprehensive digital network of attributed polygons. To accomplish this, we created an ArcInfo© GIS database using in-house protocols. The protocols consist of a shell (master file) of Arc Macro Language (AML) scripts and menus (nearly 100 files) that automate the transfer process, thus insuring that all spatial and attribute data are consistent and stored properly. The actual transfer of information from the interpreted orthophotos to a digital, geo-referenced format involved scanning, rasterizing, vectorizing, cleaning, building topology, and labeling each polygon.

The scanning technique involved a multi-step process whereby the Mylar overlay sheets produced by the photo interpreters were scanned into a digital form. The digital image file (tagged image format .tif) created from the scanned sheet was then converted from a raster image to a vector file using RSGIS-developed AMLs in ArcInfo©. The vector file was then geo-referenced to the matching digital version of the orthophoto. The essential principle of geo-referencing was to match control points (the UTM grid) as marked on the orthophotos to the same ones in the digital images. In this manner the transfer was 1-to-1.

Once scanned and registered, we removed all erroneous information such as dangling lines. After cleaning we joined the lines into polygons by building topology in the GIS program. The resulting polygons were then edge matched with those from adjacent orthophotos. Finally, we created labels for each polygon and use these to add the attribute information. Using this process we created one final coverage or spatial database for the entire project.

Attribution for all the polygons at ZION included information pertaining to map units, NVC associations, Anderson land-use classes, fire-specific designations, NWI classes, and other relevant data. Attribute items requested by the ZION fire program included height, density, and evidence of recent fire (e.g. Hgt_class, CC_Tree, Fire (Yes/NO) etc.). All of the attribute items are listed in **Table 2** and are referenced in the ZION vegetation look-up table included on the accompanying CD-ROM. Attribute data were taken directly from the interpreted photos or were added later using the orthophotos as a guide.

2.7 Map Verification and Accuracy Assessment

Map Verification

As we completed the orthophoto interpretation and digital transfer for sections of the Park, draft 1:12,000-scale hard copy vegetation maps were printed for review. In all cases we checked these draft maps against the interpreted photographs to ensure that the polygons were labeled properly and to locate any extra or missing lines. We also compared the map labels to the plot data if they fell in the same location. Copies of the revised draft map were then sent to the Park for review and taken into the field by the photo interpreters for ground-truthing. During the ground-truthing process, we collected more general observation points using the standard observation point form (**Appendix D)** and verified aerial photograph signatures using landmarks and GPS waypoints. The map and map units were then modified to correct any mistakes.

Accuracy Assessment

The AA at ZION occurred in three stages. The initial stage was conducted during the helicopter-assisted work. This involved holding back from the photo interpreters **24** plots taken throughout the course of the week-long effort. Although not an ideal way of collecting AA data, we decided that since these areas could only be accessed by helicopter we would only have "one-shot" at getting the maximum amount of data. Plots held back represented common associations that were still used in the classification but had no bearing on the mapping.

After the spatial database for ZION was created and verified it was turned over in pieces to NatureServe for assessment of the thematic accuracy. NatureServe collected the field data for the accuracy assessment during the 2001 field season, with some additional points collected in 2002. We began with the southwestern portion of the Park and proceeded north, since this mimicked the photo interpretation process. The mapping and accuracy assessment proceeded in tandem throughout the season.

As AA fieldwork was being done on a portion of the Park, we would finish mapping another portion. AA data collection would then progress to the newly completed map section. In general, work flowed from low elevation environments to high.

To allocate the appropriate number of AA points per mapped vegetation type without a completed map was a complex task. Before sampling began ecologists and field crews derived a tabular matrix, which estimated the abundance and approximate range of each vegetation map unit. The 800 samples were then provisionally split between the vegetation types proportional to their percentage of cover in the Park. For example, type "A" was expected to cover one percent of the park so was assigned 8 samples. Type "A" is restricted to low elevation environments so it would receive all 8 of those samples early in the season (since the PI team mapped low elevation areas first). Type "B", which also covers about one percent of the Park, is found throughout many environments and would receive those same 8 samples doled out gradually throughout the season as its different habitats were mapped. As each portion of the map was completed the matrix was updated to reflect the new vegetation data.

The only polygons excluded from possible selection in the AA process were within areas deemed dangerous for travel. In general, some clustering of various target types within a localized area was allowed; otherwise the selection of AA points was random.

NatureServe contracted 2, two-person teams of ecologists to collect AA data at ZION during the 2001 field season. The field crews traveled to the AA sample sites and determined the vegetation association using the vegetation key (**Appendix E**), recording primary and secondary association names (if similar to another type). They also recorded basic vegetation strata and environmental data, and percent canopy cover of the major species in each stratum (see AA point form in **Appendix D**.). Finally, they recorded other nearby vegetation types within 50 meters of the AA point. A total of 817 Accuracy Assessment points were obtained in 2001.

Although 817 sampling points were initially generated for the accuracy assessment in 2001, 521 of these points fell into only 5 types. To correct this lop-sided distribution another round of AA data was collected in 2003. Again NatureServe contracted field ecologists (only 1-team of 2 this time), which traveled to the new target sites and collected data using methods identical to the first year. Rare and infrequent map units not receiving enough study in 2001 were targeted yielding another 438 AA sample points. Between the two years, a total of 1255 points were sampled and **Figure 12** shows their locations.

Upon completion of the fieldwork, all AA data were entered into the PLOTS database and reviewed for data entry errors. Incomplete data on the field sheets, including missing GPS coordinates were corrected if possible. Final AA points were viewed in ArcView in relation to the vegetation map coverage. Actual assessment consisted of comparing the determination made in the field for each AA point to the polygon map label. These comparisons were initially made by NatureServe ecologists and reviewed by BOR. Each point was reviewed for accuracy and for errors made by the AA ecologist. In this manner, "false" errors or mismatches between a polygon and an accuracy assessment were separated from true errors. False errors were generally recognized as resulting from one of three problems:

- **GPS errors:** The point was located incorrectly (wrong polygon) due to projection issues, GPS limitations (+/- error), or the target was placed too close to a polygon boundary.
- **Ecotone errors:** A point occurred in a zone of transition between two types.
- **Intuitive errors:** A point was classified differently than the polygon label but was overruled by NatureServe and/or BOR staff. These errors were due to discrepancies between the actual cover values and what the stand was called by the field crews. Also sometimes the stand that was assessed was too small of an area (*i.e.* inclusion). Points that made no sense were removed from the assessment entirely.

Final assessments for each point were recorded in an error matrix (*i.e.*, contingency table) (**Table 6**).

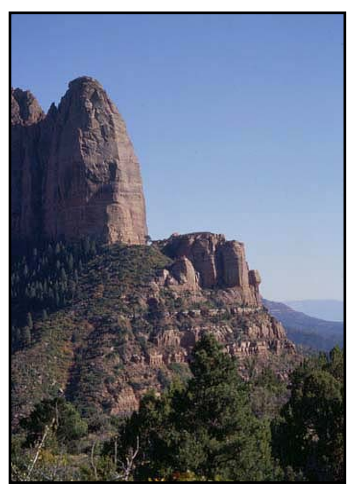


Table 2. Polygon attribute items and descriptions used in the ZION spatial database (GIS coverage).

ATTRIBUTE	**DESCRIPTION**
AREA*	Surface area of the polygon in meters squared
PERIMETER*	Perimeter of the polygon in meters
ZION_VEG#*	Unique internal polygon coding
ZION_VEG-ID*	Unique internal polygon coding
OLD_CODE	Initial Map Unit Codes (non-sequential), - BOR derived, project specific.
VEG_CODE	Final Map Unit Codes (sequential) - BOR derived, project specific.
VEG_NAME	Map Unit Scientific Description Name - BOR derived, project specific.
VEG_CNAME	Map Unit Common Description Name - BOR derived, project specific.
ECOLOGY	Ecological Groups - vegetation types sharing ecological processes.
PHYSIO	Physiognomic Groups – vegetation types sharing physiognomic features.
ECO_CODE	Ecological Systems Classification Code – NatureServe Ecological Classification
ECO_NAME	Ecological Systems Classification Name – NatureServe Ecological Classification
PHOTO	Corresponding Zion Orthophoto basemap (1-27 panels/sheets).
LOCATION	Location of polygon (Park or Environs).
CC_GRASS	Percent canopy cover of the grass/herbaceous layer.
CC_SHRUB	Percent canopy cover of the shrub layer.
CC_ TREE	Percent canopy cover of the tree layer.
	(Percent canopy cover classes: < 5%, 5 - 25%, 25 - 50%, 50 - 75%, 75 - 100%)
HGT_CLASS	Height range of the dominant vegetation layer
	(Height classes: 0-2, 2-5, 5-10, 10-20, >20 meters)
VEG_PAT	Vegetation pattern within the polygon or line
	(Vegetation pattern classes: Clumped/patchy, Homogenous, Linear)
BURN	Evidence of recent burning (Yes/No)
ASPEN	Presence of aspen in the polygon (Yes/No)
ASN_NAME	Project Community Name - NVC Association(s)
ASN_NAME2	Project Community Name - NVC Association(s) (continued)
ASN_CNAME	Project Common Community Name - synonym name of Association(s)
ASN_CNAME2	Project Common Community Name - synonym name of Association(s) (cont.)
ASN_CEGL	Community Element Global Code - Elcode link to NVC Association
ALL_KEY	NVC Code – to NVC Alliance Level
ALL_NAME	Project Alliance Name – NVC Alliance(s)
ALL_CNAME	Project Common Alliance Name – NVC Alliance(s)
NVCS_CODE	NVC Code - to NVC Formation level
CLASS NVCS	Formation Class - Class name (code)
SUBCLASS	NVC Formation Subclass - Subclass name (code)
GROUP	NVC Formation Group - Group name (code)
SUBGROUP	SUBGROUP NVC Formation Subgroup - Subgroup name (code)
FORMATION	NVC Formation - Formation name (code)
LUC_II	Land Use and Land Cover Classification System (USGS, Anderson et al. 1976)
NWI_SYS	National Wetlands Inventory Cowardian Wetland Classification System Label
NWI_SUB-S	National Wetlands Inventory Sub-system Label
NWI_CLASS	National Wetlands Inventory Class Label
NWI_SPEC-M	National Wetlands Inventory Special Modifiers
COMMENT1	General Description about the map unit and its distribution
COMMENT2	General Comment of how the map unit relates to other map units

(*****ArcInfo© default items)

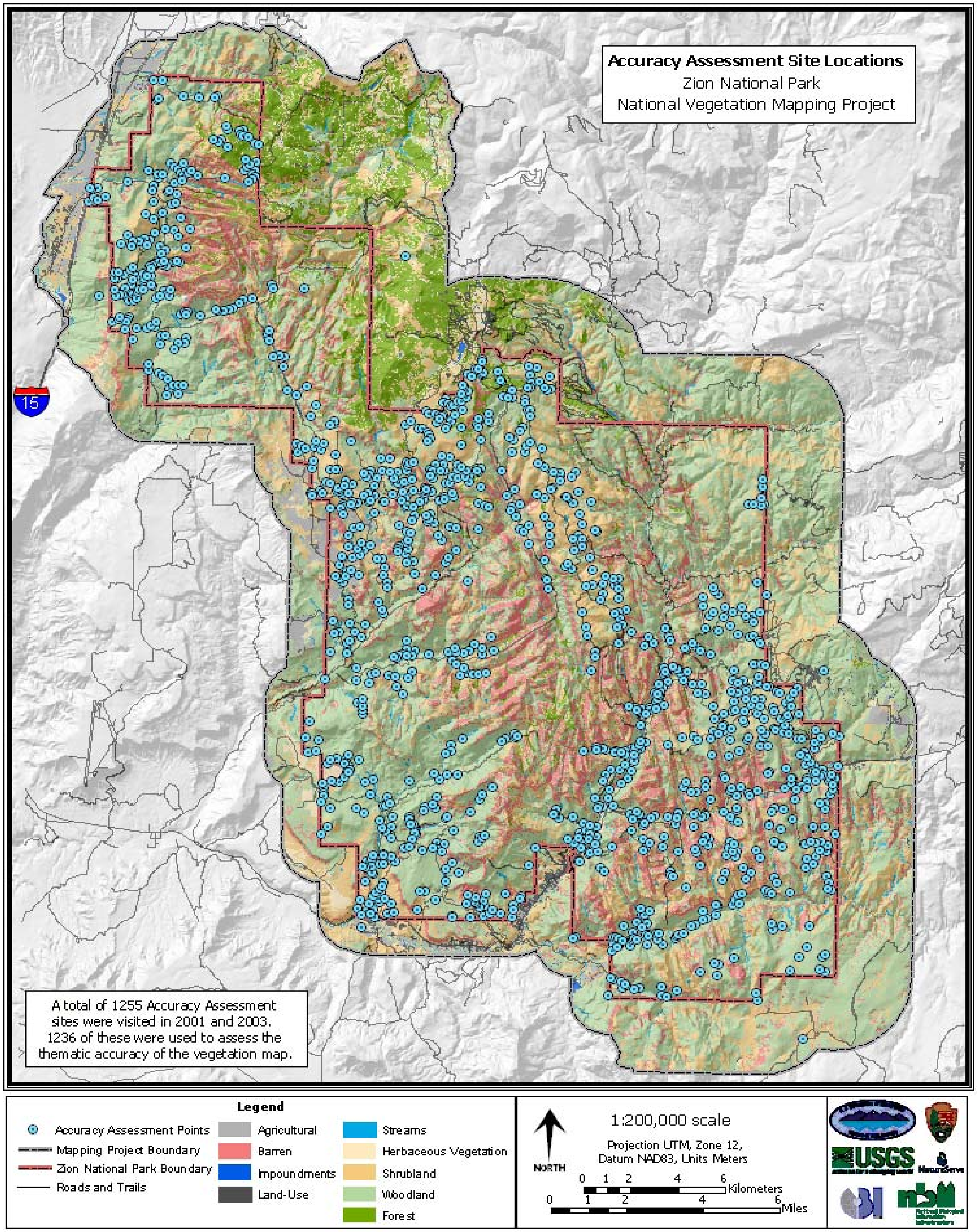


Figure 12. Locations of Accuracy Assessment Points collected at ZION.

3. RESULTS

3.1 NVC at ZION

General characteristics of the vegetation

During the course of the field work and data analyses several observations about the vegetation at ZION were made by NatureServe ecologists. These include the following:

1. During the course of the plot data collection **366** different plant species were identified by the field researchers (**Appendix H**).

2. Species common to the major bio-geographical regions around ZION contribute and intermingle in specific areas of the Park. Specifically: the Mojave Desert in the southwest, Great Basin in the west, and the Colorado Plateau in the east and northern portions.

3. The huge elevation gradient of nearly a mile (1128-2660 m, 3666-8726 ft) from Coalpits Wash to Horse Ranch Mountain and the complex landscape contribute to the high vegetation diversity. Dividing the Park into low, middle, and high elevation zones is useful to describe the vegetation of Zion National Park.

4. In hot, arid regions such as ZION, solar isolation and therefore aspect, plays a large role in determining where different vegetation types will occur. Therefore, generalized elevation zones overlap and are only approximations that vary with aspect and other local conditions.

5. The area of low elevation vegetation in the Park ranges from just below 1130 m (3700 ft) to approximately 1280m (4200 ft) depending on aspect, and is largely restricted to the South and Southwestern portions of Zion. Vegetation at these sites includes desert and semi-desert shrublands dominated by *Coleogyne ramosissima* (blackbrush), *Artemisia tridentata* (big sagebrush), *Atriplex canescens* (fourwing saltbush), *Ericameria nauseosa* (rabbitbrush), *Sarcobatus vermiculatus* (greasewood), *Gutierrezia sarothrae* (snakeweed), and *Ephedra nevadensis* (Mormon tea). There are smaller areas of desert grasslands, e.g., *Pleuraphis jamesi* (galleta) and *Aristida* spp. (threeawn). This desert vegetation may grade into sparse *Juniperus osteosperma* (Utah juniper) or *Pinus monophylla* (single-leaf pinyon) woodlands. There are also sparse badland types in eroded areas of Chinle and Moenkopi formation that are dominated by *Eriogonum corymbosum* (buckwheat), *Atriplex canescens* or *Ephedra nevadensis*.

6. Lowland riparian forests and woodlands are dominated by *Populus fremontii* (Fremont cottonwood), *Fraxinus velutina* (velvet ash), *Acer negundo* (box elder), or the introduced *Elaeagnus angustifolia* (Russian olive). Riparian and wetland areas may be dominated by herbaceous or shrub species such as *Juncus balticus* (baltic rush), *Baccharis emoryi* (seepwillow), or *Salix exigua* (sandbar willow). Some of these riparian forests and woodlands lack understories or are dominated by non-native species. This configuration is common in areas of high use such as along trails, roads, and campgrounds.

7. Middle elevation vegetation ranges from approximately 1220-2080 m (4000-6800 ft) and is often dominated by woodlands of *Juniperus osteosperma, J. scopulorum* (Rocky Mountain juniper), *Pinus edulis* (two-needle pinyon) and/or *P. monophylla*. The woodland understories are dominated by *Amelanchier utahensis* (Utah serviceberry), *Arctostyphylos patula* (greenleaf manzanita), *Artemisia tridentata, Cercocarpus montanus* (mountain mahogany), *C. ledifolius* (curl-leaf mountain-mahogany), *Purshia stansburiana* (Stansbury cliff-rose), *Quercus turbinella* (turbinella live oak), or *Q. gambelii* (gambel oak). *Juniperus osteosperma* and *Pinus monophylla* woodlands typically occur at lower elevations and on southern exposures, and *Pinus edulis* woodlands at higher elevations. *Juniperus scopulorum* and *Pinus ponderosa* (ponderosa pine) woodlands become important in this zone depending on aspect. Pure stands of oak will also occur depending on fire history.

Middle-elevation riparian types are similar to low elevation types where streams are perennial except that *Populus angustifolia* (narrow-leaf cottonwood) may be present.

8. Higher elevation vegetation is approximately 1830-2600 m (6000-8600 ft) and is characterized by montane vegetation types such as *Pinus ponderosa* woodland and forest, *Populus tremuloides* (quaking aspen) forest, *Pseudotsuga menziesii* (Douglas-fir) forests, *Abies concolor* (white fir) forests, and mixed montane shrublands and grasslands. *Quercus gambelii* is also an important shrub in this zone. Vegetation typical of this zone can extend to middle elevations in canyons where cold air drains and in more mesic environments, such as north-facing slopes. *Populus tremuloides* stands occur on more mesic sites and *Artemisia nova* (black sagebrush) shrublands on dry, rocky exposed sites.

9. There are also several "edaphic controlled" vegetation types such as *Artemisia filifolia* on sand deposits below sandstone cliffs of Navajo and perhaps other geologic formations. Sparse vegetation types such as *Pinus ponderosa* and *Cercocarpus intricatus* (littleleaf mountain-mahogany) slickrock, *Shepherdia rotundifolia* (round-leaf buffaloberry) on slumps, talus slopes, and shale/clay barrens are also present.

10. A result of the Great Basin and Colorado Plateaus floras mixing at ZION is a zone of introgression between two pinyon pines, *Pinus monophylla* and *Pinus edulis*. Individual trees may have hybrid characteristics of both species, namely the number of needles per fascicle; single-needled for *P. monophylla* and two per fascicle for *P. edulis*. We initially thought that *P. monophylla* would dominate woodlands in the western part of the Park switching to *P. edulis* in the eastern part, with Zion Canyon as the breaking point. However by looking at the plot data the actual trend was a little more complicated.

    Plotting the distribution of species as recorded in the plot data (**Figure 12**) you can see that *Pinus monophylla* is more common at lower elevations in the southern and western portions of ZION, with *Pinus edulis* more typical in the eastern and northern higher elevations. Based on this analysis, the zone of introgression appears very broad and not well defined. The contact zone for the two species seems to run northwest to southeast in ZION with elevation likely playing a large role.

    It should be noted that plots containing putative hybrids of *Pinus edulis* and *P. monophylla* were not included in this analysis, but could be added as a third category. Studies of other plant taxa distributions within the Park could also be done using this database.

11. Several vegetation types were very problematic to classify. The most difficult were the mixes of montane shrubs. In some areas of ZION, there are complicated, repeating mixes of montane shrubland associations dominated or co-dominated by several different shrubs such as *Amelanchier utahensis, Cercocarpus montanus, Quercus gambelii,* or *Q. turbinella* with varying amounts of *Arctostyphylos patula, Artemisia tridentata, Purshia stansburiana, Juniperus osteosperma, Pinus edulis* or *P. monophylla.*

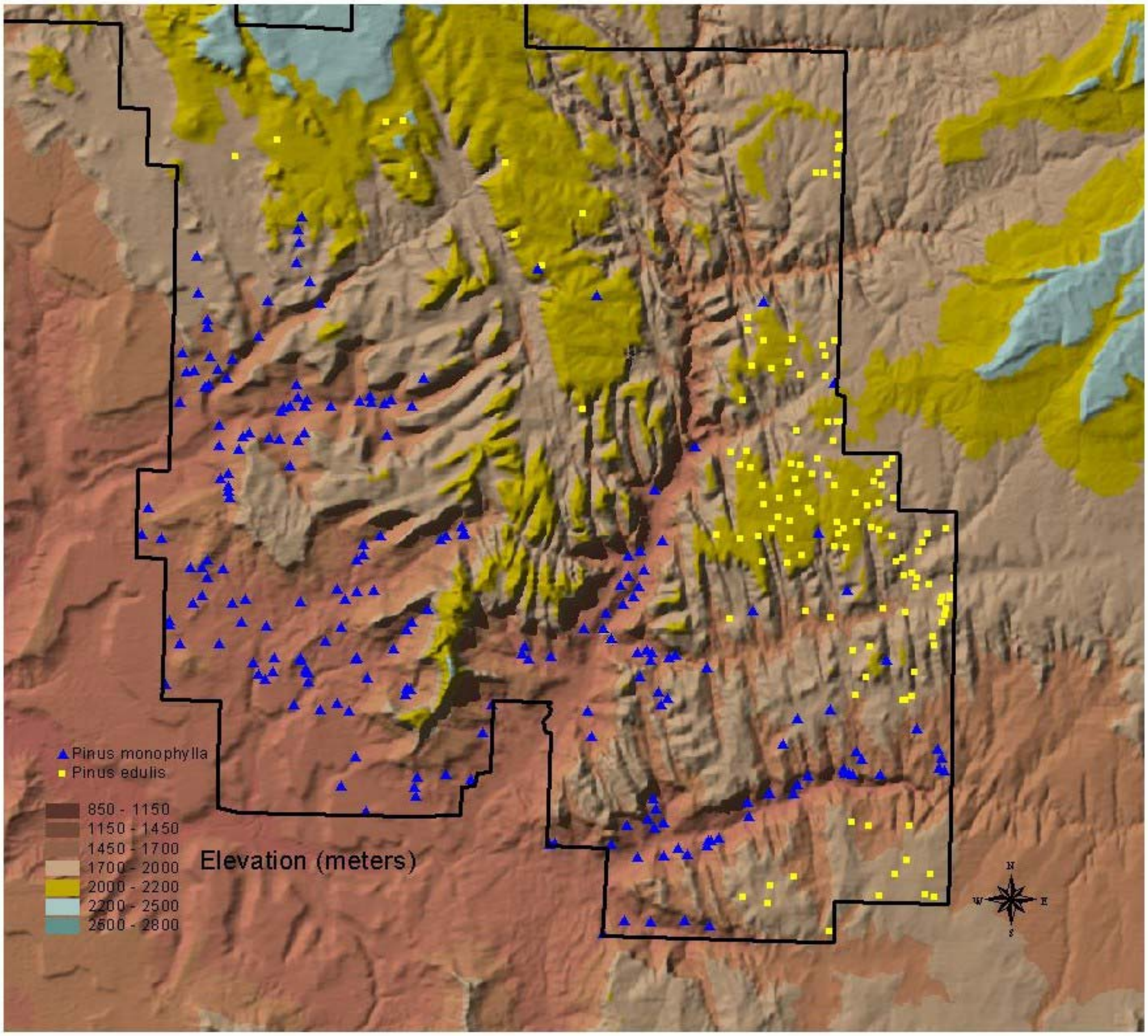


Figure 13. Location and elevation of ZION plots with Pinus edulis and Pinus monophylla.
(Figure created by Michael Schindel, TNC 2001)

We speculate that various environmental factors including fire history play important roles in controlling the distribution of these species at ZION. Although common as individual associations elsewhere in the Park, when the montane shrubs/trees intermix they form a repeatable pattern. This can be evidenced on the cobbly slopes in the Kolob Canyon region of ZION. In these instances it is difficult to determine whether the species form an unique association, a complex or mosaic of many associations, or a broad ecotone

Another group we found difficult to classify was the sparse vegetation. The distribution of sparse vegetation at ZION seemed to vary environmentally. For example it occurred on sandstone slickrock, colluvial slopes and badlands shale substrates. It also varied physiognomically, such as being tree, shrub, or forb dominated. Sparse vegetation at ZION also exhibited a wide difference in species diversity between sites. This may have been due to anthropogenic disturbance (such as past

12. agricultural activity) that effected both species composition (i.e. native vs. non-native) and abundance. Combined, these variables all compounded the classification efforts.

13. Some of the most unique vegetation types at ZION occur on "hanging gardens". These gardens are found in hydrophytic habitats associated with infrequent seeps and springs along xeric canyon walls throughout the Colorado Plateau region. The hanging gardens of ZION were not included in this study, and no plot data were collected for them, due to their small size, infrequent occurrence, often remote locations. However, they are important to recognize in any discussion of the vegetation of Zion National Park because they support endemic plants that are confined to these wet locations in the midst of an arid region. Fowler (1995) conducted a biogeographic study of the hanging gardens of the Colorado Plateau, including some of those found in ZION. He grouped the 84 gardens he sampled into five vegetation types: fern, fern-columbine, columbine, reedgrass, and fern-thistle.

    Welsh (1989) found that hanging garden vegetation varies from canyon to canyon as well as between separate alcoves within a canyon. The vegetation of hanging gardens generally has some common species that are found at most of the hanging gardens, for example *Maianthemum stellatum*, *Adiantum capillusveneris*, *Adiantum pedatum*, and *Mimulus* spp. Numerous endemics occur in these habitats and some only occur in one or two sites. These include: *Aquilegia micrantha, Carex curatorum, Cirsium rydbergii, Erigeron kachensis* (one occurrence outside of the hanging gardens in the Abajo Mts.), *Erigeron sionis*, *E. zothecinus, Platanthera zothecina, Mimulus eastwoodiae, Perityle specuicola,* and *Primula specuicola.*

NVC Associations

The final classification for ZION resulted in **95** associations. Of that total, 53 are existing NVC associations and 42 are new local associations that were defined by this project. The classification results reflect both the high diversity of vegetation in the Park and the lack of comprehensive vegetation classification work in this region. This is especially true with the montane shrublands, and pinyon and juniper woodlands. **Table 3** has a complete list of Zion plant associations that were described by this study, and **Appendix F** provides complete descriptions for each of them.

3.2 Photo-interpretation and Map Units

We recognized and delineated 76 map units on the true color aerial photographs for ZION. This included 17 barren or unvegetated units, 48 vegetation units and 11 Anderson Level II (1976) land-use units (**Table 4**). All map units were developed from a combination of an initial NVC vegetation classification provided by NatureServe with input from Park biologists and BOR ecologists, fieldwork, and preliminary photo-interpretation.

Please reference **Appendix I**. for detailed descriptions and representative photos for all vegetation map units.

An example of the Intermittent Stream Map Unit #72 and Tinaja (natural water holes / tanks) Map Unit #17 at ZION

Table 3. List of NVC Plant Associations found at Zion National Park.

Plant Association Name	Common Name	Elcode*
Mesic Herbaceous Vegetation		
Carex nebrascensis Herbaceous Vegetation	Nebraska Sedge Herbaceous Vegetation	CEGL001813
Carex utriculata Herbaceous Vegetation	Beaked Sedge Herbaceous Vegetation	CEGL001562
Equisetum (arvense, variegatum) Herbaceous Vegetation	(Field Horsetail, Variegated Scouringrush) Herbaceous Vegetation	CEGL005148
Juncus balticus Herbaceous Vegetation	Baltic Rush Herbaceous Vegetation	CEGL001838
Upland Grasslands		
Bouteloua gracilis - Hesperostipa comata Dwarf-shrub Herbaceous Vegetation	Blue Grama - Needle-and-Thread Dwarf-shrub Herbaceous Vegetation	NEW CEGL002932
Bromus inermis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation	Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	CEGL005264
Bromus tectorum Semi-natural Herbaceous Vegetation	Cheatgrass Herbaceous Semi-natural Herbaceous Vegetation	CEGL003019
Hesperostipa comata Great Basin Herbaceous Vegetation	Needle-and-Thread Great Basin Herbaceous Vegetation	CEGL001705
Muhlenbergia (pungens, montana) - Heterotheca villosa Herbaceous Vegetation	(Sandhill Muhly, Mountain Muhly) - Hairy Goldenaster Herbaceous Vegetation	NEW CEGL002938
Pleuraphis jamesii Herbaceous Vegetation	James' Galleta Herbaceous Vegetation	CEGL001777
Poa pratensis Semi-natural Seasonally Flooded Herbaceous Vegetation	Kentucky Bluegrass Semi-natural Seasonally Flooded Herbaceous Vegetation	CEGL003081
Sporobolus cryptandrus Great Basin Herbaceous Vegetation	Sand Dropseed Great Basin Herbaceous Vegetation	CEGL002691
Thinopyrum intermedium Semi-natural Herbaceous Vegetation	Intermediate Wheatgrass Semi-natural Herbaceous Vegetation	NEW CEGL002935

Xeric Shrublands		
Coleogyne ramosissima Shrubland	Blackbrush Shrubland	CEGL001332
Coleogyne ramosissima / Pleuraphis jamesii Shrubland	Blackbrush / James' Galleta Shrubland	CEGL001334
Ephedra nevadensis – Lichen Sparse Vegetation	Nevada Jointfir – Lichen Sparse Vegetation	NEW CEGLOO2976
Ephedra nevadensis Basalt Shrubland	Nevada Jointfir Basalt Shrubland	NEW CEGL002936
Eriogonum corymbosum Badlands Sparse Vegetation	Crispleaf buckwheat Badlands Sparse Vegetation	NEW CEGL002979
Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii Dwarf-shrubland	Broom Snakeweed – (Prickly Pear) / James' Galleta Dwarf-shrubland	CEGL002690
Upland Shrublands		
Amelanchier utahensis Shrubland	Utah Serviceberry Shrubland	CEGL001067
Arctostaphylos patula Shrubland	Greenleaf Manzanita Shrubland	NEW CEGL002696
Arctostaphylos patula - Artemisia tridentata ssp. vaseyana Shrubland	Greenleaf Manzanita - Mountain Big Sagebrush Shrubland	NEW CEGL002694
Arctostaphylos patula - Quercus gambelii - (Amelanchier utahensis) Shrubland	Greenleaf Manzanita - Gambel Oak - (Utah Serviceberry) Shrubland	NEW CEGL002695
Arctostaphylos pungens Shrubland	Mexican Manzanita Shrubland	CEGL000958
Artemisia filifolia Colorado Plateau Shrubland	Sand Sagebrush Colorado Plateau Shrubland	CEGL002697
Artemisia nova / Elymus elymoides Dwarf-shrubland	Black Sagebrush / Bottlebrush Dwarf-shrubland	CEGL001418
Artemisia nova / Hesperostipa comata Dwarf-shrubland	Black Sagebrush / Needle-and-Thread Dwarf-shrubland	CEGL001425
Artemisia nova / Poa fendleriana Dwarf-shrubland	Black Sagebrush / Muttongrass Dwarf-shrubland	NEW CEGL002698
Artemisia tridentata / Bouteloua gracilis Shrubland	Big Sagebrush / Blue Grama Shrubland	CEGL000995

Artemisia tridentata - (Ericameria nauseosa) / Bromus tectorum Shrubland	Big Sagebrush - (Rubber Rabbitbrush) / Cheatgrass Shrubland	NEW CEGL002699
Artemisia tridentata ssp. tridentata / Pascopyrum smithii - (Elymus lanceolatus) Shrubland	Basin Big Sagebrush / Western Wheatgrass - (Streamside Wild Rye) Shrubland	CEGL001017
Artemisia tridentata ssp. vaseyana / Hesperostipa comata Shrubland	Mountain Big Sagebrush / Needle-and-Thread Shrubland	NEW CEGL002931
Atriplex canescens Shrubland	Fourwing Saltbush Shrubland	CEGL001281
Atriplex canescens - Artemisia tridentata Shrubland	Fourwing Saltbush - Big Sagebrush Shrubland	CEGL001282
Cercocarpus intricatus Slickrock Sparse Vegetation	Littleleaf Mountain-mahogany Slickrock Sparse Vegetation	NEW CEGL002977
Cercocarpus montanus Rock Pavement Sparse Vegetation	Mountain-mahogany Rock Pavement Sparse Vegetation	NEW CEGL002978
Chrysothamnus viscidiflorus / Poa pratensis Shrub Herbaceous Vegetation	Green Rabbitbrush / Kentucky Bluegrass Shrub Herbaceous Vegetation	NEW CEGL002933
Ericameria nauseosa / Bromus tectorum Shrubland	Rubber Rabbitbrush / Cheatgrass Shrubland	CEGL002937
Ericameria nauseosa Sand Deposit Sparse Vegetation	Rubber Rabbitbrush Sand Deposit Sparse Vegetation	NEW CEGL002980
Purshia stansburiana - Arctostaphylos patula Shrubland	Stansbury Cliff-rose - Greenleaf Manzanita Shrubland	NEW CEGL002948
Quercus gambelii - Cercocarpus montanus / (Carex geyeri) Shrubland	Gambel Oak - Mountain-mahogany / (Geyer's Sedge) Shrubland	CEGL001113
Quercus gambelii / Amelanchier utahensis Shrubland	Gambel Oak / Utah Serviceberry Shrubland	CEGL001110
Quercus gambelii / Artemisia tridentata Shrubland	Gambel Oak / Big Sagebrush Shrubland	CEGL001111
Quercus gambelii / Poa fendleriana Shrubland	Gambel Oak / Muttongrass Shrubland	NEW CEGL002949
Quercus gambelii / Symphoricarpos oreophilus Shrubland	Gambel Oak / Mountain Snowberry Shrubland	CEGL001117
Quercus turbinella - (Amelanchier utahensis) Colluvial Shrubland	Turbinella Live Oak - (Utah Serviceberry) Colluvial Shrubland	NEW CEGL002950
Symphoricarpos oreophilus / Poa pratensis Semi-natural Shrubland	Mountain Snowberry / Kentucky Bluegrass Semi-natural Shrubland	NEW CEGL002951
Tetradymia canescens - Ephedra viridis Shrubland	Gray Horsebrush - Mormon-tea Shrubland	NEW CEGL002973

Riparian Shrublands		
Baccharis emoryi Shrubland	Emory Seepwillow Shrubland	NEW CEGL002974
Salix exigua / Barren Shrubland	Coyote Willow / Barren Shrubland	CEGL001200
Salix exigua / Mesic Graminoids Shrubland	Coyote Willow / Mesic Graminoids Shrubland	CEGL001203
Salix ligulifolia / Carex utriculata Shrubland	Strapleaf Willow / Beaked Sedge Shrubland	NEW CEGL002975
Pluchea sericea Seasonally Flooded Shrubland	Arrow-weed Seasonally Flooded Shrubland	CEGL003080
Riparian Woodlands		
Acer negundo / Brickellia grandiflora Woodland	Box-elder / Tasselflower Brickelbush Woodland	NEW CEGL002692
Acer negundo / Disturbed Understory Woodland	Box-elder / Disturbed Understory Woodland	NEW CEGL002693
Fraxinus anomala Woodland	Single-leaf Ash Woodland	NEW CEGL002752
Populus fremontii / Baccharis emoryi Woodland	Fremont Cottonwood / Emory Seepwillow Woodland	NEW CEGL002946
Populus fremontii / Betula occidentalis Wooded Shrubland	Fremont Cottonwood / Water Birch Wooded Shrubland	NEW CEGL002981
Populus fremontii / Salix exigua Forest	Fremont Cottonwood / Coyote Willow Forest	CEGL000666
Populus fremontii - Fraxinus velutina Woodland	Fremont Cottonwood - Velvet Ash Woodland	CEGL000942
Deciduous Forests		
Acer grandidentatum / Quercus gambelii Forest	Bigtooth Maple / Gambel Oak Forest	CEGL000559
Populus tremuloides - Abies concolor / Poa pratensis Forest	Quaking Aspen - White Fir / Kentucky Bluegrass Forest	NEW CEGL002947
Populus tremuloides - Abies concolor / Symphoricarpos oreophilus Forest	Quaking Aspen - White Fir / Mountain Snowberry Forest	CEGL000523
Populus tremuloides / Quercus gambelii / Symphoricarpos oreophilus Forest	Quaking Aspen / Gambel Oak / Mountain Snowberry Forest	CEGL000598
Populus tremuloides / Symphoricarpos oreophilus / Tall Forbs Forest	Quaking Aspen / Mountain Snowberry / Tall Forbs Forest	CEGL000615

Coniferous Woodlands		
Juniperus osteosperma / Artemisia tridentata Woodland	Utah Juniper / Big Sagebrush Woodland	CEGL000730
Juniperus scopulorum - Quercus gambelii Woodland	Rocky Mountain Juniper - Gambel Oak Woodland	NEW CEGL002967
Pinus edulis - Juniperus osteosperma / Arctostaphylos patula Woodland	Two-needle Pinyon - Utah Juniper / Greenleaf Manzanita Woodland	NEW CEGL002939
Pinus edulis - Juniperus osteosperma / Cercocarpus intricatus Woodland	Two-needle Pinyon - Utah Juniper / Littleleaf Mountain-mahogany Woodland	CEGL000779
Pinus edulis - Juniperus osteosperma / Purshia stansburiana Woodland	Two-needle Pinyon - Utah Juniper / Stansbury Cliff-rose Woodland	CEGL000782
Pinus edulis - Juniperus spp. / Artemisia tridentata Woodland	Two-needle Pinyon - Juniper species / Big Sagebrush Woodland	CEGL000776
Pinus edulis - Juniperus spp. / Cercocarpus montanus Woodland	Two-needle Pinyon - Juniper species / Mountain-mahogany Woodland	CEGL000780
Pinus edulis - Juniperus spp. / Quercus gambelii Woodland	Two-needle Pinyon - Juniper species / Gambel Oak Woodland	CEGL000791
Pinus edulis / Cercocarpus ledifolius Woodland	Two-needle Pinyon / Curl-leaf Mountain-mahogany Woodland	NEW CEGL002940
Pinus monophylla - Juniperus osteosperma Woodland	Singleleaf Pinyon - Utah Juniper Woodland	CEGL000829
Pinus monophylla - Juniperus osteosperma / Artemisia tridentata Woodland	Singleleaf Pinyon - Utah Juniper / Big Sagebrush Woodland	CEGL000832
Pinus monophylla - Juniperus osteosperma / Artemisia nova Woodland	Singleleaf Pinyon - Utah Juniper / Black Sagebrush Woodland	CEGL000831
Pinus monophylla - Juniperus osteosperma / Cercocarpus montanus - Quercus gambelii Woodland	Singleleaf Pinyon - Utah Juniper / Mountain-mahogany - Gambel Oak Woodland	NEW CEGL002968
Pinus monophylla - Juniperus osteosperma / Coleogyne ramosissima Woodland	Singleleaf Pinyon - Utah Juniper / Blackbrush Woodland	NEW CEGL002971
Pinus monophylla - Juniperus osteosperma / Gutierrezia sarothrae / Pleuraphis jamesii Woodland	Singleleaf Pinyon - Utah Juniper / Snakeweed / James' Galleta Woodland	NEW CEGL002970
Pinus monophylla - Juniperus osteosperma / Hesperostipa comata Woodland	Singleleaf Pinyon - Utah Juniper / Needle-and-Thread Woodland	NEW CEGL002969
Pinus monophylla - Juniperus osteosperma / Quercus turbinella Woodland	Singleleaf Pinyon - Utah Juniper / Turbinella Live Oak Woodland	NEW CEGL002941

Pinus monophylla - Juniperus osteosperma / (Shepherdia rotundifolia, Amelanchier utahensis) Woodland	Singleleaf Pinyon - Utah Juniper / (Roundleaf Buffaloberry, Utah Serviceberry) Woodland	NEW CEGL002942
Pinus ponderosa / Arctostaphylos patula Woodland	Ponderosa Pine / Greenleaf Manzanita Woodland	CEGL000842
Pinus ponderosa / Artemisia nova Woodland	Ponderosa Pine / Black Sagebrush Woodland	CEGL000846
Pinus ponderosa / Bromus inermis Semi-natural Woodland	Ponderosa Pine / Smooth Brome Semi-natural Woodland	NEW CEGL002943
Pinus ponderosa / Pteridium aquilinum Woodland	Ponderosa Pine / Northern Bracken Woodland	NEW CEGL002944
Pinus ponderosa / Quercus gambelii Woodland	Ponderosa Pine / Gambel Oak Woodland	CEGL000870
Pinus ponderosa Slickrock Sparse Vegetation	Ponderosa Pine Slickrock Sparse Vegetation	NEW CEGL002972
Coniferous Forests		
Abies concolor / Acer grandidentatum Forest	White Fir / Bigtooth Maple Forest	CEGL000241
Abies concolor / Arctostaphylos patula Forest	White Fir / Greenleaf Manzanita Forest	CEGL000242
Abies concolor / Quercus gambelii Forest	White Fir / Gambel Oak Forest	CEGL000261
Abies concolor / Symphoricarpos oreophilus Forest	White Fir / Mountain Snowberry Forest	CEGL000263
Pseudotsuga menziesii / Quercus gambelii Forest	Douglas-fir / Gambel Oak Forest	CEGL000452
Pseudotsuga menziesii / Symphoricarpos oreophilus Forest	Douglas-fir / Mountain Snowberry Forest	CEGL000462
Pseudotsuga menziesii / Acer granditentatum Forest	Douglas-fir / Bigtooth Maple Forest	CEGL000419

***ELCODE** represents NatureServe's internal database tracking code for each recognized plant association.
- NVC associations first defined at Zion during this project are indicated in the ELCODE column (**NEW**).

Table 4. Map units used for Zion National Park.
The units are organized into ecological groups. "Level" refers to whether the map unit represents a NVC plant association or alliance (NVC unless otherwise noted), local plant community/plant population, or a land use class. Anderson Land Use Classes are identified by Roman numerals.

Map Code	Map Unit Name	Map Unit Common Name	Level
Unvegetated Surfaces			
1	Carmel Formation (Limestone)	Carmel Formation (Limestone)	N/A
2	Temple Cap (Sandstone)	Temple Cap (Sandstone)	N/A
3	Navajo Formation (Sandstone)	Navajo Formation (Sandstone)	N/A
4	Kayenta Formation (Sandstone)	Kayenta Formation (Sandstone)	N/A
5	Moenave Formation (Sandstone)	Moenave Formation (Sandstone)	N/A
6	Chinle Formation – Petrified Forest (Shale)	Chinle Formation – Petrified Forest (Shale)	N/A
7	Chinle Formation – Shinarump (Shale)	Chinle Formation – Shinarump (Shale)	N/A
8	Moenkopi Formation (Conglomerate)	Moenkopi Formation (Conglomerate)	N/A
9	Kaibab Formation (Limestone)	Kaibab Formation (Limestone)	N/A
10	Basalt Talus	Basalt Talus	N/A
11	Unvegetated Volcanic Cinders and Cinder Cones	Unvegetated Volcanic Cinders and Cinder Cones	N/A
12	Slides (Fans and Slumps)	Slides (Fans and Slumps)	N/A
13	Gullies and Eroded Lands	Gullies and Eroded Lands	N/A
14	Sand Bars and Beaches	Sand Bars and Beaches	N/A

15	Volcanic and Basalt Cliffs	Volcanic and Basalt Cliffs	N/A
16	Snags	Snags	N/A
17	Tinajas (natural water holes / tanks)	Tinajas (natural water holes / tanks)	N/A
Upland Grasslands			
18	*Poa pratensis - Bromus inermis* Semi-natural Grassland Complex	Perennial Disturbed Grassland Complex	Complex
19	*Bromus tectorum* Semi-natural Herbaceous Vegetation	Cheatgrass Annual Disturbed Grassland	Association
20	*Pleuraphis jamesii* Herbaceous Vegetation	James' Galleta Herbaceous Vegetation	Association
21	*Sporobolus cryptandrus* Great Basin Herbaceous Vegetation	Sand Dropseed Great Basin Herbaceous Vegetation	Association
22	Dry Meadow Mixed Herbaceous Vegetation Mosaic	Dry Meadow Mixed Herbaceous Vegetation Mosaic	Mosaic
Mesic Herbaceous Vegetation			
23	*Carex spp.- Juncus spp.* Wet Meadow Herbaceous Vegetation Mosaic	Sedge-Rush Wet Meadow Herbaceous Vegetation Mosaic	Mosaic
Wetland Herbaceous Vegetation			
24	*Typha spp., Scirpus spp.* Emergent Wetland Complex	Cattail, Bulrush, Emergent Wetland Complex	Complex
Xeric Shrublands			
25	*Coleogyne ramosissima* Shrubland Complex	Blackbrush Shrubland Complex	Complex
26	*Ephedra nevadensis - Eriogonum corymbosum* Badlands Sparse Vegetation	Painted Desert Sparsely Vegetated Alliance	Alliance
27	*Ephedra nevadensis* Basalt Shrubland	Nevada Joint-fir Basalt Shrubland	Association
28	*Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii* Dwarf-shrubland	Snakeweed - (Prickly-pear species) / James' Galleta Dwarf-shrubland	Association
29	*Prosopis glanulosa* Shrub Stands	Honey Mesquite Shrub Stands	Local Plant Community[3]

Upland Shrublands			
30	*Artemisia filifolia* Colorado Plateau Shrubland	Sand Sagebrush Colorado Plateau Shrubland	Association
31	*Artemisia tridentata* Shrubland Complex	Big Sagebrush Shrubland Complex	Complex
32	*Ericameria (Chrysothamnus) spp.* Shrubland Complex	Rabbitbrush Shrubland Complex	Complex
33	*Cercocarpus intricatus Slickrock* Sparse Vegetation	Littleleaf Mountain-mahogany Slickrock Sparse Vegetation	Association
34	*Quercus turbinella - (Amelanchier utahensis)* Colluvial Shrubland	Talus Mixed Shrubland	Association
35	*Symphoricarpos oreophilus / Poa pratensis* Semi-natural Shrubland	Mountain Snowberry / Kentucky Bluegrass Semi-natural Shrubland	Association
36	*Artemisia nova Dwarf-shrubland* Complex	Black Sagebrush Dwarf-shrubland Complex	Complex
37	*Arctostaphylos patula* Shrubland Complex	Greenleaf Manzanita Shrubland Complex	Complex
38	*Arctostaphylos patula - Quercus gambelii - (Amelanchier utahensis)* Shrubland	Greenleaf Manzanita - Gambel Oak - (Utah Serviceberry) Shrubland	Association
39	*Quercus gambelii* Shrubland Alliance	Gambel Oak Shrubland Alliance	Alliance
40	*Mixed Mountain* Shrubland Complex	Mixed Mountain Shrubland Complex	Complex
41	*Amelanchier utahensis* Shrubland	Utah Serviceberry Shrubland	Association
42	*Cercocarpus montanus* Rock Pavement Sparse Vegetation	Mountain-mahogany Rock Pavement Sparse Vegetation	Association
Riparian Shrublands			
43	*Baccharis emoryi* Shrubland	Emory Seepwillow Shrubland	Association
44	*Salix exigua* Shrubland Alliance	Sandbar Willow Shrubland Alliance	Alliance
45	*Tamarix spp.* Temporarily Flooded Shrubland	Tamarisk spp. Temporarily Flooded Shrubland	Association

46	*Pluchea sericea* Seasonally Flooded Shrubland	Arrow-weed Seasonally Flooded Shrubland	Association
47	*Salix ligulifolia / Carex utriculata* Shrubland	Strapleaf Willow / Beaked Sedge Shrubland	Association
Riparian Woodlands			
48	*Fraxinus anomala* Woodland	Single-leaf Ash Woodland	Association
49	*Acer negundo* Woodland Alliance	Boxelder Woodland Alliance	Alliance
50	*Populus fremontii* Woodland Complex	Fremont Cottonwood Woodland Complex	Complex
51	*Populus fremontii - Fraxinus velutina* Woodland	Fremont Cottonwood – Velvet Ash Woodland	Association
52	*Elaeagnus angustifolia* Semi-natural Woodland	Russian Olive Semi-natural Woodland	Association
Deciduous Forests			
53	*Quercus gambelii* Woodland	Gambel Oak Woodland	Association
54	*Acer grandidentatum / Quercus gambelii* Forest	Bigtooth Maple / Gambel Oak Forest	Association
55	*Populus tremuloides* Forest Complex	Quaking Aspen Forest Complex	Complex
Coniferous Woodlands			
56	*Juniperus spp. / Artemisia tridentata* Woodland Complex	Juniper / Big Sagebrush Woodland Complex	Complex
57	*Pinus spp. - Juniperus spp.* Woodland Complex	Pinyon - Juniper Woodland Complex	Complex
58	*Pinus spp. - Juniperus spp. / Quercus gambelii* Woodland Complex	Pinyon - Juniper / Gambel Oak Woodland Complex	Complex
59	*Pinus ponderosa* Slickrock Sparse Vegetation	Ponderosa Pine Slickrock Sparse Vegetation	Association
60	*Pinus ponderosa / Arctostaphylos patula* Woodland	Ponderosa Pine / Greenleaf Manzanita Woodland	Complex
61	*Pinus ponderosa / Quercus gambelii* Woodland Complex	Ponderosa Pine / Gambel Oak Woodland Complex	Complex
62	*Pinus ponderosa* / Mixed Herbaceous Woodland Complex	Ponderosa Pine / Mixed Herbaceous Woodland Complex	Complex

Coniferous Forests			
63	*Pinus ponderosa* Forest (Closed Canopy)	Ponderosa Pine Forest (Closed Canopy)	Association
64	*Pseudotsuga menziesii* Forest Alliance	Douglas-fir Forest Alliance	Alliance
65	*Abies concolor* Forest Alliance	White Fir Forest Alliance	Alliance
Land-use			
66	Transportation, Communications, and Utilities	Transportation, Communications, and Utilities	Level II
67	Mixed Urban or Built-up Land	Mixed Urban or Built-up Land	Level II
68	Croplands and Pastures	Croplands and Pastures	Level II
69	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas	Level II
70	Other Agricultural Lands	Other Agricultural Lands	Level II
71	Perennial Streams	Perennial Streams	Level II
72	Intermittent Streams	Intermittent Streams	Level II
73	Reservoirs	Reservoirs	Level II
74	Canals	Canals	Level II
75	Stock Ponds	Stock Ponds	Level II
76	Strip Mines, Quarries, and Gravel Pits	Strip Mines, Quarries, and Gravel Pits	Level II

[1] **Complex:** a group of plant associations that cannot be mapped individually on the aerial photographs but occur together predictably on the landscape**.** Complexes typically are composed of associations with similar physiognomies, thus are more difficult to tell apart on the photos.

[2] **Mosaic:** individual associations are recognizable on the aerial photography but are too intermixed to map as separate polygons.

[3] **Local Plant Community:** represents discrete stands of vegetation that are too small and/or occur too infrequently to classify.

3.3 Relationship between Map Units and Plant Associations

The ZION map units represent a compromise among the detail of the NVC, the needs of the Park and the limitations of the photography. As a result, the ZION mapping scheme does not exactly match the NVC. Rather, the vegetation map units are linked (i.e. "crosswalked") to the NVC plant associations.

Here are the possible scenarios: 1) When a plant association or alliance has an unique photo signature and can be readily delineated on the photos, the map unit adopts the plant association/alliance name. This is considered a one-to-one relationship. 2) When plant associations occur in stands too small to map or when related plant associations share the same signature and *are not* recognizable on the photos, several plant associations are lumped into a single map unit called a complex. 3) Similarly, when associations *are* recognizable on the aerial photography but are too intermixed to map as separate polygons a mosaic designation is used; these are many-to-one situations. 4) Next, when more than one phase of a single plant association can be recognized on the photos, a plant association is split into several map classes. This is a one-to-many situation. 5) Finally, non-vegetated areas and vegetation types not recognized by the NVC receive special map unit designations.

Below is a comprehensive breakdown of the crosswalking of the NVC associations to the map units for ZION:

(One Association-to-One Map Class)

-Map Units Representing Single NVC Units (either existing or new)

The following map units were created from the NVC and represent established or provisional plant associations or alliances that could be discerned and delineated on the aerial photography.

Map Code	Map Unit / *NVC Plant Association / ALLIANCE*
19	*Bromus tectorum* Semi-natural Herbaceous Vegetation
	Bromus tectorum Semi-natural Herbaceous Vegetation
20	*Pleuraphis jamesii* Herbaceous Vegetation
	Pleuraphis jamesii Herbaceous Vegetation
21	*Sporobolus cryptandrus* Great Basin Herbaceous Vegetation
	Sporobolus cryptandrus Great Basin Herbaceous Vegetation
26	*Ephedra nevadensis - Eriogonum corymbosum* Badlands Sparse Vegetation (Alliance)
	PAINTED DESERT SPARSELY VEGETATED ALLIANCE
	Ephedra nevadensis / Lichen Sparse Vegetation*
	Eriogonum corymbosum Badlands Sparse Vegetation*
27	*Ephedra nevadensis* Basalt Shrubland
	Ephedra nevadensis Basalt Shrubland
28	*Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii* Dwarf-shrubland
	Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii Dwarf-shrubland
30	*Artemisia filifolia* Colorado Plateau Shrubland
	Artemisia filifolia Colorado Plateau Shrubland

33 *Cercocarpus intricatus* Slickrock Sparse Vegetation
Cercocarpus intricatus Slickrock Sparse Vegetation

34 *Quercus turbinella - (Amelanchier utahensis)* Colluvial Shrubland
Quercus turbinella - (Amelanchier utahensis) Colluvial Shrubland

35 *Symphoricarpos oreophilus / Poa pratensis* Semi-natural Shrubland
Symphoricarpos oreophilus / Poa pratensis Semi-natural Shrubland

38 *Arctostaphylos patula - Quercus gambelii - (Amelanchier utahensis)* Shrubland
Arctostaphylos patula - Quercus gambelii - (Amelanchier utahensis) Shrubland

41 *Amelanchier utahensis* Shrubland
Amelanchier utahensis Shrubland

42 *Cercocarpus montanus* Rock Pavement Sparse Vegetation
Cercocarpus montanus Rock Pavement Sparse Vegetation

43 *Baccharis emoryi* Shrubland
Baccharis emoryi Shrubland

44 *Salix exigua* Shrubland Alliance
SALIX (EXIGUA, INTERIOR) TEMPORARILY FLOODED SHRUBLAND ALLIANCE
Salix exigua / Barren Shrubland*
Salix exigua / Mesic Graminoids Shrubland*

45 *Tamarix* spp. Temporarily Flooded Shrubland
Tamarix spp. Temporarily Flooded Shrubland

46 *Pluchea sericea* Seasonally Flooded Shrubland
Pluchea sericea Seasonally Flooded Shrubland

47 *Salix ligulifolia / Carex utriculata* Shrubland
Salix ligulifolia / Carex utriculata Shrubland

48 *Fraxinus anomala* Woodland
Fraxinus anomala Woodland

49 *Acer negundo* Woodland Alliance
ACER NEGUNDO TEMPORARILY FLOODED WOODLAND ALLIANCE
Acer negundo / Brickellia grandiflora Woodland*
Acer negundo / Disturbed Understory Woodland*

51 *Populus fremontii - Fraxinus velutina* Woodland
Populus fremontii - Fraxinus velutina Woodland

52 *Elaeagnus angustifolia* Semi-natural Woodland
Elaeagnus angustifolia Semi-natural Woodland

54 *Acer grandidentatum / Quercus gambelii* Forest
Acer grandidentatum / Quercus gambelii Forest

59 *Pinus ponderosa* Slickrock Sparse Vegetation
Pinus ponderosa Slickrock Sparse Vegetation

60 *Pinus ponderosa / Arctostaphylos patula* Woodland
Pinus ponderosa / Arctostaphylos patula Woodland

64 *Pseudotsuga menziesii* Forest Alliance
PSEUDOTSUGA MENZIESII FOREST ALLIANCE
Pseudotsuga menziesii / Quercus gambelii Forest*
Pseudotsuga menziesii / Symphoricarpos oreophilus Forest*
Pseudotsuga menziesii / Acer granditentatum Forest*

65 *Abies concolor* Forest Alliance
ABIES CONCOLOR FOREST ALLIANCE
Abies concolor / Acer grandidentatum Forest*
Abies concolor / Arctostaphylos patula Forest*
Abies concolor / Quercus gambelii Forest*
Abies concolor / Symphoricarpos oreophilus Forest*

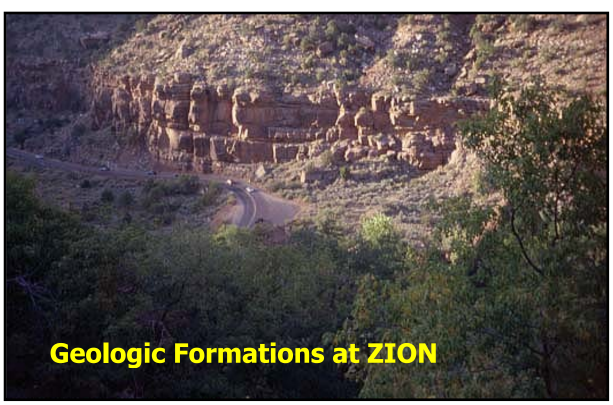
*Represents documented associations that could not be mapped separately from other associations within the Alliance.

(Many Associations-to-One Map Class)

-Map Units Representing Aggregations of Plant Associations (Mosaic)

Associations are recognizable on the aerial photography but are too intermixed to map as separate polygons.

Map Code	Map Unit *NVC Plant Associations*
22	Dry Meadow Mixed Herbaceous Vegetation Mosaic
	Bouteloua gracilis - Hesperostipa comata Herbaceous Vegetation
	Hesperostipa comata Great Basin Herbaceous Vegetation
	Muhlenbergia (pungens, montana) - Heterotheca villosa Herbaceous Vegetation
	Thinopyrum intermedium Herbaceous Vegetation Herbaceous Vegetation
23	Sedge-Rush Wet Meadow Herbaceous Vegetation Mosaic
	Carex utriculata Herbaceous Vegetation
	Carex nebrascensis Herbaceous Vegetation
	Equisetum (arvense, variegatum) Herbaceous Vegetation
	Juncus balticus Herbaceous Vegetation



(Many Associations-to-One Map Class)

-Map Units Representing Aggregations of Plant Associations (Complex)

In cases where closely related plant associations could not be distinguished on the photos, they were combined into a single map unit.

Map Code	Map Unit / *NVC Plant Associations*
18	Perennial Disturbed Grassland Complex
	Bromus inermis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation
	Poa pratensis Semi-natural Seasonally Flooded Herbaceous Alliance
25	*Coleogyne ramosissima* Shrubland Complex
	Atriplex canescens Shrubland
	Coleogyne ramosissima Shrubland
	Coleogyne ramosissima / Pleuraphis jamesii Shrubland
31	*Artemisia tridentata* Shrubland Complex
	Artemisia tridentata / Bouteloua gracilis Shrubland
	A. tridentata - (Ericameria nauseosa) / Bromus tectorum Shrubland
	A. tridentata ssp. tridentata / Pascopyrum smithii - (Elymus lanceolatus) Shrubland
	Artemisia tridentata ssp. vaseyana / Hesperostipa comata Shrubland
	Atriplex canescens - Artemisia tridentata Shrubland
	Tetradymia canescens - Ephedra viridis Shrubland
32	*Ericameria (Chrysothamnus)* spp. Shrubland Complex
	Chrysothamnus viscidiflorus / Poa pratensis Shrub Herbaceous Vegetation [Provisional]
	Ericameria nauseosa / Bromus tectorum Shrubland
	Ericameria nauseosa Sand Deposit Sparse Vegetation
36	*Artemisia nova* Dwarf-shrubland Complex
	Artemisia nova / Elymus elymoides Dwarf-shrubland
	Artemisia nova / Hesperostipa comata Dwarf-shrubland
	Artemisia nova / Poa fendleriana Dwarf-shrubland
37	*Arctostaphylos patula* Shrubland Complex
	Arctostaphylos patula - Artemisia tridentata ssp. vaseyana Shrubland
	Arctostaphylos patula Shrubland
	Purshia stansburiana - Arctostaphylos patula Shrubland
40	Mixed Mountain Shrubland Complex*
	Arctostaphylos pungens Shrubland
	Arctostaphylos patula - Artemisia tridentata ssp. vaseyana Shrubland *
	Arctostaphylos patula Shrubland *
	Purshia stansburiana - Arctostaphylos patula Shrubland*
	Quercus turbinella - (Amelanchier utahensis) Colluvial Shrubland *
	Cercocarpus montanus Rock Pavement Sparse Vegetation*

50 *Populus fremontii* Woodland Complex
Populus fremontii / Betula occidentalis Wooded Shrubland
Populus fremontii / Salix exigua Forest
Populus fremontii / Baccharis emoryi Woodland

55 *Populus tremuloide*s Forest Complex
Populus tremuloides - Abies concolor / Symphoricarpos oreophilus Forest
Populus tremuloides - Abies concolor / Poa pratensis Forest
Populus tremuloides / Symphoricarpos oreophilus / Tall Forbs Forest
Populus tremuloides / Quercus gambelii / Symphoricarpos oreophilus Forest

56 *Juniperus spp. / Artemisia tridentata* Woodland Complex
Juniperus osteosperma / Artemisia tridentata Woodland
Pinus edulis - Juniperus spp. / Artemisia tridentata Woodland
Pinus monophylla - Juniperus osteosperma / Artemisia tridentata Woodland

57 *Pinus spp. - Juniperus spp.* Woodland Complex,
Pinus edulis - Juniperus osteosperma / Cercocarpus intricatus Woodland
Pinus edulis - Juniperus osteosperma / Purshia stansburiana Woodland
Pinus edulis - Juniperus osteosperma / Arctostaphylos patula Woodland
Pinus edulis - Juniperus osteosperma / Cercocarpus montanus Woodland
Pinus edulis - Juniperus osteosperma / Cercocarpus ledifolius Woodland
Pinus monophylla - Juniperus osteosperma / Artemisia nova Woodland
Pinus monophylla - Juniperus osteosperma / Quercus turbinella Woodland
Pinus monophylla - Juniperus osteosperma / (Shepherdia rotundifolia Amelanchier Utahensis) Woodland
Pinus monophylla - Juniperus osteosperma / Cercocarpus montanus - Quercus gambelii Woodland
Pinus monophylla - Juniperus osteosperma / Gutierrezia sarothrae Woodland
Pinus monophylla - Juniperus osteosperma / Pleuraphis jamesii Woodland
Pinus monophylla - Juniperus osteosperma / Coleogyne ramosissima Woodland

58 *Pinus spp. - Juniperus spp. / Quercus gambelii* Woodland Complex
Juniperus scopulorum - Quercus gambelii Woodland
Pinus edulis - Juniperus spp. / Quercus gambelii Woodland

61 *Pinus ponderosa / Quercus gambelii* Woodland Complex
Pinus ponderosa / Quercus gambelii Woodland
Pinus ponderosa / Pteridium aquilinum Woodland [Provisional]

62 *Pinus ponderosa* / Mixed Herbaceous Woodland Complex
Pinus ponderosa / Bromus inermis Semi-natural Woodland
Pinus ponderosa / Artemisia nova Woodland

***** The Mixed Mountain Shrubland Complex represents an unique map unit that occurs on a specific habitat in ZION. This map unit contains an intricate mix of both an uncommon shrub association (*Arctostaphylos pungens* Shrubland) and other more common shrub associations at ZION (denoted by *). This map unit likely represents a broad ecotone containing many common species.

(One Association-to-Many Map Classes)

-Map Units Representing Multiple Phases of a Plant Association
The following map units represent plant associations that are divided into multiple map units because of structural differences easily discerned on the aerial photographs. Map units used to delineate these types can be considered local variations of the plant communities or plant populations.

Map Code	Map Unit / *NVC Plant Associations / ALLIANCE*
39	*Quercus gambelii* Shrubland Alliance
	QUERCUS GAMBELII SHRUBLAND ALLIANCE
	Quercus gambelii / Amelanchier utahensis Shrubland
	Quercus gambelii / Artemisia tridentata Shrubland
	Quercus gambelii - Cercocarpus montanus / (Carex geyeri) Shrubland
	Quercus gambelii / Symphoricarpos oreophilus Shrubland
	Quercus gambelii / Poa fendleriana Shrubland
53	*Quercus gambelii* Woodland (Alliance)
	QUERCUS GAMBELII SHRUBLAND ALLIANCE
	Quercus gambelii / Amelanchier utahensis Shrubland
	Quercus gambelii / Artemisia tridentata Shrubland
	Quercus gambelii / Symphoricarpos oreophilus Shrubland
	Quercus gambelii / Poa fendleriana Shrubland
	(Note: This map unit represents Gambel Oak shrubs that have grown into large trees under favorable conditions. The NVC still considers this type as part of the shrubland Alliance.)

-Map Units Representing No Association
These three map units were created for ZION to describe vegetation that had no corresponding NVC association for the following reasons, respectively:

- (24) Represents infrequent or rare types that can not be classified to an association since no plots or points were collected;
- (29) Represents types occurring in patches smaller than the minimum mapping unit of 0.5 ha;
- (63) Represents situations were the associated species can not be seen on the aerial photography (i.e. closed canopy).

Map Code	Map Unit
24	*Typha spp., Scirpus spp*. Emergent Wetland Complex
29	*Prosopis glandulosa* Shrub Stands
63	*Pinus ponderosa* Forest (Closed Canopy)

3.4 Vegetation Map

A total of 246,696 acres (99,838 ha) comprising Zion National Park and its environs was mapped. Of this total, NVC-related vegetation map units covered 210,169 acres (85,055 ha). The remaining acreage was mapped using land cover and unvegetated map units. Of all the map units, the most frequent was #3 Navajo Formation (Sandstone) with 4050 polygons ranging from barren slickrock to steep cliffs and slopes. The most frequent vegetation map unit was #39 Gambel Oak Shrubland Alliance with 3638 polygons. The most abundant map unit in terms of area was #57, Pinyon - Juniper Woodland Complex type covering 56,026 acres or about 23% of the project area. Frequencies of map units (*i.e.*, number of polygons) along with acreage per map unit are listed in **Table 5**.

Table 5. Total acreage and frequency of map units for Zion National Park.

Map Code	Map Unit Common Name	Polygons			Acres		
		Park	Environs	Total	Park	Environs	Total
1	Carmel Formation (Limestone)	39	181	220	89.3	473.0	562.3
2	Temple Cap (Sandstone)	38	17	55	38.4	24.6	62.9
3	Navajo Formation (Sandstone)	2,660	636	3,296	22,037.1	2,396.8	24,434.0
4	Kayenta Formation (Sandstone)	90	3	93	196.5	36.0	232.5
5	Moenave Formation (Sandstone)	46	1	47	98.8	4.7	103.4
6	Chinle Formation – Petrified Forest (Shale)	117	73	190	387.2	167.6	554.9
7	Chinle Formation – Shinarump (Shale)	44	66	110	69.4	170.3	239.7
8	Moenkopi Formation (Conglomerate)	73	50	123	227.5	177.5	404.9
9	Kaibab Formation (Limestone)	1	16	17	0.6	47.8	48.4
10	Basalt Talus	116	116	232	230.6	263.2	493.8
11	Unvegetated Volcanic Cinders and Cinder Cones	1	0	1	0.8	0.0	0.8
12	Slides (Fans and Slumps)	336	60	396	526.4	137.3	663.7
13	Gullies and Eroded Lands	184	92	276	234.3	139.3	373.6
14	Sand Bars and Beaches	119	81	200	92.1	54.5	146.7
15	Volcanic and Basalt Cliffs	17	22	39	32.0	38.3	70.2
16	Snags	44	0	44	21.2	0.0	21.2
17	Tinajas (natural water holes / tanks)	8	4	12	0.8	1.4	2.2
18	Perennial Disturbed Grassland Complex	86	217	303	272.0	716.9	988.9
19	Cheatgrass Annual Disturbed Grassland	70	137	207	138.4	485.0	623.3
20	James' Galleta Herbaceous Vegetation	31	24	55	257.4	778.1	1,035.5
21	Sand Dropseed Great Basin Herbaceous Vegetation	103	8	111	143.6	33.6	177.3
22	Dry Meadow Mixed Herbaceous Vegetation Mosaic	300	687	987	554.2	1,678.7	2,232.9
23	Sedge-Rush Wet Meadow Herbaceous Vegetation Mosaic	68	316	384	101.5	764.0	865.5
24	Cattail, Bulrush, Emergent Wetland Complex	2	71	73	2.6	118.6	121.2
25	Blackbrush Shrubland Complex	69	104	173	681.3	1,109.7	1,791.0
26	Painted Desert Sparsely Vegetated Alliance	24	39	63	409.7	254.4	664.1
27	Nevada Joint-fir Basalt Shrubland	12	24	36	200.9	251.9	452.8

Map Code	Map Unit Common Name	Polygons			Acres		
		Park	Environs	Total	Park	Environs	Total
28	Snakeweed - (Prickly-pear species) / James' Galleta Dwarf-shrubland	232	180	412	641.8	1,204.5	1,846.3
29	Honey Mesquite Shrub Stands	0	6	6	0.0	2.0	2.0
30	Sand Sagebrush Colorado Plateau Shrubland	41	2	43	123.8	3.2	127.0
31	Big Sagebrush Shrubland Complex	628	780	1,408	2,200.5	4,544.4	6,744.9
32	Rabbitbrush Shrubland Complex	197	241	438	357.2	730.0	1,087.2
33	Littleleaf Mountain-mahogany Slickrock Sparse Vegetation	1,049	199	1,248	3,723.0	907.7	4,630.7
34	Talus Mixed Shrubland	784	87	871	2,795.7	317.9	3,113.6
35	Mountain Snowberry / Kentucky Bluegrass Semi-natural Shrubland	43	25	68	186.0	94.6	280.6
36	Black Sagebrush Dwarf-shrubland Complex	147	67	214	463.8	445.7	909.4
37	Greenleaf Manzanita Shrubland Complex	1,702	543	2,245	7,860.1	3,161.6	11,021.6
38	Greenleaf Manzanita - Gambel Oak - (Utah Serviceberry) Shrubland	144	41	185	1,000.1	427.3	1,427.3
39	Gambel Oak Shrubland Alliance	2,164	1,035	3,199	10,990.4	6,588.7	17,579.1
40	Mixed Mountain Shrubland Complex	720	414	1,134	3,985.9	2,531.7	6,517.6
41	Utah Serviceberry Shrubland	75	11	86	461.5	131.8	593.3
42	Mountain-mahogany Rock Pavement Sparse Vegetation	60	68	128	294.8	448.8	743.6
43	Emory Seepwillow Shrubland	96	25	121	53.4	12.9	66.3
44	Sandbar Willow Shrubland Alliance	52	8	60	34.9	5.5	40.4
45	Tamarisk spp. Temporarily Flooded Shrubland	10	118	128	3.4	195.6	199.0
46	Arrow-weed Seasonally Flooded Shrubland	0	3	3	0.0	7.8	7.8
47	Strapleaf Willow / Beaked Sedge Shrubland	5	19	24	4.9	33.8	38.7
48	Single-leaf Ash Woodland	0	1	1	0.0	0.9	0.9
49	Boxelder Woodland Alliance	42	2	44	67.4	1.2	68.6
50	Fremont Cottonwood Woodland Complex	264	126	390	424.9	243.6	668.5
51	Fremont Cottonwood – Velvet Ash Woodland	548	252	800	1,136.0	490.6	1,626.6
52	Russian Olive Semi-natural Woodland	1	42	43	0.7	72.3	72.9
53	Gambel Oak Woodland	780	788	1,568	2,046.4	2,432.6	4,479.0
54	Bigtooth Maple / Gambel Oak Forest	98	233	331	1,362.2	7,767.6	9,129.9
55	Quaking Aspen Forest Complex	99	383	482	297.1	2,395.8	2,692.8
56	Juniper / Big Sagebrush Woodland Complex	203	421	624	2,298.0	3,917.6	6,215.6

Map Code	Map Unit Common Name	Polygons			Acres		
		Park	Environs	Total	Park	Environs	Total
57	Pinyon - Juniper Woodland Complex	1,594	785	2,379	34,323.0	21,672.3	55,995.3
58	Pinyon - Juniper / Gambel Oak Woodland Complex	1,084	791	1,875	7,111.5	7,674.0	14,785.5
59	Ponderosa Pine Slickrock Sparse Vegetation	746	70	816	4,922.4	803.8	5,726.2
60	Ponderosa Pine / Greenleaf Manzanita Woodland	1979	455	2,434	15,743.7	5,787.0	21,530.7
61	Ponderosa Pine / Gambel Oak Woodland Complex	1,730	455	2,185	8,763.1	3,675.1	12,438.2
62	Ponderosa Pine / Mixed Herbaceous Woodland Complex	113	64	177	608.1	317.4	925.6
63	Ponderosa Pine Forest (Closed Canopy)	26	17	43	241.6	385.9	627.5
64	Douglas-fir Forest Alliance	552	48	600	1,717.7	131.0	1,848.7
65	White Fir Forest Alliance	290	161	451	2,861.1	2,333.0	5,194.1
66	Transportation, Communications, and Utilities	31	56	87	2,94.6	1,195.0	1,489.6
67	Mixed Urban or Built-up Land	67	439	506	71.9	574.1	646.0
68	Croplands and Pastures	30	183	213	478.6	3,873.2	4,351.8
69	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas	0	14	14	0.0	100.2	100.2
70	Other Agricultural Lands	1	25	26	0.5	35.9	36.4
71	Perennial Streams	41	20	61	474.6	213.7	688.3
72	Intermittent Streams	208	91	299	488.8	242.9	731.7
73	Reservoirs	5	16	21	2.3	142.1	144.5
74	Canals	0	3	3	0.0	3.9	3.9
75	Stock Ponds	23	165	188	4.6	47.7	52.2
76	Strip Mines, Quarries, and Gravel Pits	2	49	51	1.8	79.1	80.8
Totals							
Barren/Unvegetated Lands (1-17)		3,933	1418	5,351	24,283	4,132	28,415
Natural/Semi-natural Vegetation Map Units (18-66)		19,094	10,649	29,743	12,2162	89,283	211,445
Planted/Cultivated, Land-use/Land Cover (66-76)		377	1,005	1,382	1,523	5,313	6,836
All Map Units		23,404	13,72	36,476	147,968	98,728	246,696

3.5 Accuracy Assessment

2001 Accuracy Assessment

The 2001 accuracy assessment effort yielded 817 points. However, upon comparing them to the vegetation map we calculated a very low accuracy of 15%. During subsequent analysis we determined the cause of the low accuracy to be a result of a difference between the projection datum of the vegetation map, North America Datum 1983, (NAD83) and the datum used by the AA field teams (North America Datum 1927 or NAD27). This difference resulted in an offset that placed the field crews about 200 meters north of their targets.

By re-projecting the vegetation map into NAD27 we corrected for the offset giving us the correct location of the AA points and improving our accuracy. However, the offset effectively removed the stratification in the pre-selection procedure and placed the target points in a more random distribution. Specifically, 521 or 64% of the points fell into only 5 map classes. Further, we found that the largest portion of the points (285, 35%) occured in the Pinyon-Juniper Woodland Complex (Map code 57), which also happened to cover the largest area in ZION (34,323 acres or 23% of the Park). The result was a lop-sided distribution with the majority of the map units under-represented.

Another issue caused by the offset was the positional accuracy of the field teams in relation to the lines on the map. Since the original target locations were not sampled, the 10 meter buffer used to avoid sampling in ecotones or in the wrong polygon due to GPS error was rendered ineffective. This resulted in points occurring directly on lines between polygons with no clear way of determining which polyon was assessed. To help solve this problem, we created a halo or buffer around each point of 20 meters to represent a conservative estimate of combined map and GPS errors. We then overlaid these on the vegetation map and scored them by how many polygons they fell into. Points clearly contained in one polygon were given a high score, or a high probability that this vegetation polygon was the actual one assessed. Buffered points that were associated with 2 or more vegetation polygons were listed in order of the area of their intersection. This resulted in a list with each of the possible vegetation types in descending order of their area of intersection with the buffered point.

2003 Accuracy Assessment

Based on the 2001 lop-sided distribution another round of accuracy assessment data collection was conducted in 2003. For this session, we specifically targeted the under-represeted and unsampled map units. The projection discrepancy was addressed and using only one, 2-person crew we collected an additional 438 AA sample points in the correct locations. The 2003 data was combined with the 2001 data yielding a total of 1255 data points.

Accuracy Assessment Analysis

Analysis of the AA points involved a point by point review in two stages. During stage one, an initial assessment of the AA field call versus the vegetation polygon was conducted by NatureServe. At this time, the actual field form data were evaluated for consistency between the assigned map unit name and the actual recorded foliar cover values of the dominant species. As a result some of the AA points were changed to reflect the species cover values. For example, an AA point assessed as "Ponderosa Pine Slickrock Sparse Vegetation" with only a 5% cover of Ponderosa pine and 15% cover of Littleleaf Mountain-mahogany would be changed to "Littleleaf Mountain-mahogany Slickrock Sparse Vegetation". Fewer than 45 points were renamed following this review.

During the second stage, we compared each point to the vegetation map by creating a GIS layer of the AA points and spatially joining this to the vegetation layer. In a stepwise fashion, AA points that clearly mathced a polygon were scored as correct, points that justifiably matched any of the polygons in a 20-m buffer were scored correct (i.e. the second call matched a neighboring polygon), and finally polygons that did not match at all were misses.

In the course of analysis 19 points were removed due to extreme differences in location caused by questionable GPS reception (i.e. +- >50 meter error) or obvious GPS recording errors as compared to the indended targets. This left 1236 points that were compared to the vegetation map. By comparing these points we were able to calculate an overall thematic accuracy of **82%**. **Table 6** presents the accuracy assessment scores and confidence intervals for each map unit assessed along with the values for the entire map.

Table 6. Contingency table (error matrix) for vegetation mapping at Zion National Park.

Reference Data (Accuracy Assessment Field Data) (columns); Sample Data (Polygon Map Data) (rows)

Map Code	18	19	20	21	22	23	24	25	26	27	28	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	47	49	50	51	53	54	55	56	57	58	59	60	61	62	63	64	65	Samples	Commission Error % Correct	90% Confidence Interval -	90% Confidence Interval +
18	5				2	1								1					1	2																								12	42%	18	71
19		13												1																														14	93%	74%	99%
20			4								1		2					1																										8	50%	24%	76%
21		7		0												1																												8	0	0	26%
22	3	2			13													4																										22	59%	39%	76%
23	8					3							1																															12	25%	10%	50%
24																																												0	N/A	N/A	N/A
25								16				1																																17	94%	78%	99%
26									13																																			13	100%	83%	100%
27										5			1																															6	83%	46%	98%
28		1						1	1		11																								1									15	73%	50%	88%
30		1										9																																10	90%	65%	99%
31	1		1						1				36								2													3	2									46	78%	68%	88%
32								4					2	13																														19	68%	44%	85%
33															23				1																2									26	88%	75%	96%
34									1			1	1			20																			2									25	80%	64%	90%
35																	2				1																							3	67%	20%	97%
36													2					13			1																							16	81%	62%	93%
37															1	2			26	2	1	1													4	1		3						41	63%	51%	75%
38																			1	8																		1						10	80%	50%	95%
39					1											3				1	101							1			1	1		3	2	3			1					118	86%	81%	91%
40																1			3		3	11						1				1			2	1								23	48%	27%	67%
41																					1		10																					11	91%	69%	99%
42																								3																				3	100%	46%	100%
43																									15				1															16	94%	77%	99%
44	1																									2			3	1				1										8	25%	7%	58%
47																											1																	1	100%	10%	100%
49																												8				1												9	89%	61%	99%
50																													18	4														22	82%	66%	92%
51																					1									20		2			2									25	80%	64%	90%
53																							1								30	2		3										36	83%	73%	93%
54																					2											11												13	85%	62%	96%
55																																	13											13	100%	93%	100%
56								1					1																					7	9									18	39%	22%	58%
57					1							1	1	1		1			2											1					302	12			1					323	93%	91%	95%
58																2			1		1											2			1	50						1		58	86%	69%	100%
59																			1																2		29	4						36	81%	70%	92%
60																2			1	2	1														1		1	54	2					64	84%	77%	91%
61																					1								1			1			1	2		1	54	4			1	66	82%	74%	90%
62																					1																			11			1	13	85%	62%	96%
63																				1																					1			2	50%	5%	95%
64																																										10	1	11	91%	69%	99%
65																																										1	23	24	96%	84%	100%
Samples	18	24	5	0	17	4	0	22	16	5	12	12	47	16	24	32	2	18	37	16	117	12	11	3	15	2	1	10	23	26	31	21	13	17	333	69	30	63	58	15	1	12	26				
Correct	5	13	4	0	13	3	0	16	13	5	11	9	36	13	23	20	2	13	26	8	101	11	10	3	15	2	1	8	18	20	30	11	13	7	302	50	29	54	54	11	1	10	23				
Omission Error	28%	54%	80%	N/A	76%	75%	N/A	73%	81%	100%	92%	75%	77%	81%	96%	63%	100%	72%	70%	50%	86%	92%	91%	100%	100%	100%	100%	80%	78%	77%	97%	52%	100%	41%	91%	72%	97%	86%	93%	73%	100%	83%	88%				
90% Confidence -	14%	37%	38%	N/A	57%	32%	N/A	56%	62%	62%	70%	50%	67%	62%	84%	47%	32%	52%	58%	30%	81%	71%	69%	46%	85%	32%	10%	50%	62%	62%	92%	31%	83%	23%	88%	63%	92%	70%	87%	50%	10%	60%	75%				
90% Confidence +	48%	74%	98%	N/A	89%	97%	N/A	88%	93%	1%	99%	90%	87%	93%	100%	79%	100%	87%	82%	70%	91%	99%	99%	100%	100%	100%	100%	95%	89%	90%	100%	69%	100%	64%	94%	81%	100%	100%	99%	88%	100%	96%	96%				

Total Correct = 1017
Total Samples = 1236

OVERALL TOTAL ACCURACY = 82% **OVERALL KAPPA INDEX = 80%** [Pchance = 0.10] **OVERALL 90% UPPER AND LOWER CONFIDENCE INTERVAL: 80%** and **84%**

Using the Accuracy Assessment Contingency Table: The contingency table or error matrix is an array of numbers set out in rows and columns corresponding to a particular vegetation map unit relative to the actual vegetation type as verified on the ground. The column headings represent the vegetation classification as determined in the field and the row headings represent the vegetation classification taken from the vegetation map. The highlighted diagonal indicates the number of points assessed in the field that agree with the map label. Conversely, the inaccuracies of each map unit are described as both errors of inclusion (user's or commission errors) and errors of exclusion (producer's or omission errors). By reading across this table (*i.e.*, rows) one can calculate the percent error of commission, or how many polygons for each map unit were incorrectly labeled according to the field ecologist. By reading down the table (*i.e.*, columns) one can calculate the percent error of omission, or how many polygons for that type were left off the map. Numbers "on the diagonal" tell the user how well the map unit was interpreted and how confident they can be in using it. Numbers "off the diagonal" yield important information about the deficiencies of the map including which types were under- or over-represented.

Common Map Errors

Of the assessed map units, some had lower than expected levels of accuracy. By carefully examining these discrepancies we found some common issues that seem to explain most of the errors, these include:

1. Perspective: Many of the errors occurred when a polygon was classified with a very similar, but different map unit than the one identified by the field ecologist. This can happen because the photo interpreter and the field ecologist see the vegetation differently. For example, the photo interpreter sees the cover of shrubs and herbaceous vegetation over a large area, while the field ecologist assesses the cover in a much smaller area. Also the field ecologist can thoroughly assess the understory whereas the interpreter may have his view partially or completely blocked by overstory canopy. Different perspectives can lead to different estimates of cover and differing conclusions as to the correct plant association or map unit.

- *Example:* Ten errors of omission were recorded for the Talus Mixed Shrubland where the map showed them to be various other shrublands and woodlands. This likely happened in part due to the field ecologists being able to see a talus substrate for only a small subsection of the entire polygon. Whereas, the photo-interpreter either could not see the talus substrate or viewed the mixed talus shrubland as a small inclusion within a larger vegetation type.

2. Cover cut-offs: Discrepancies with some map units arose from the NVC, which depends on an arbitrary cutoff of shrub cover to separate herbaceous communities from shrublands. At ZION, the cutoff between grasslands and shrublands was 25% shrub cover, which was very difficult for the photo interpreters to see.

- *Example:* In some instances we mapped sites as Sand Dropseed Great Basin Herbaceous Vegetation but they were assessed as Big Sagebrush Shrubland Complex. The resulting commission errors likely resulted from big sagebrush occurring in the stands but not at a high level. The low cover of sagebrush allowed the understory grasses to appear more abundant on the aerial photos causing these areas to be mapped as grasslands.

3. Shrubland vs. Woodland: A majority of the omission and commission errors at ZION appeared to occur between woodlands/forests and their understory shrub component. In some cases stands were mapped as shrublands but assessed as a woodland/forest with the same shrub in the understory. Conversely, mapped woodlands/forests were assessed as the understory shrubland. These discrepancies likely arose again because of the different perspectives of the photo interpreter and the field ecologists, where the field team either saw enough trees in a small area to call it woodland or didn't see enough.

Example: Sites mapped as Greenleaf Manzanita Shrubland Complex were assessed as Ponderosa Pine / Greenleaf Manzanita Woodland. Similarly, sites mapped as either Ponderosa Pine / Gambel Oak Woodland Complex or Pinyon - Juniper / Gambel Oak Woodland Complex were assessed as Gambel Oak Shrubland Alliance. Finally some errors of commission occurred between the mapping of Gambel Oak Shrubland Alliance and the AA field teams' assessment of Pinyon - Juniper / Gambel Oak Woodland Complex. These likely represent situations where the pinyon pine and juniper trees were either locally abundant but not consistent throughout the polygon or were not abundant enough to appear on the aerial photos.

4. Transition areas: Finally the high variability in the terrain at ZION created many transition areas were species of different map units overlapped (i.e. broad ecotones). This was especially true of the shrub species. Both mapping and assessing these areas proved to be challenging. The landscape perspective of the aerial photos allowed these areas to be mapped separately as complexes/mosaics if they proved to repeat consistently across ZION. Unfortunately the field ecologists did not have this ability.

- *Example:* The Mixed Mountain Shrubland Complex gave a very distinct photo signature and occurred repeatedly on slopes in the northwestern corner of ZION. However, this type contained many shrub and tree species characteristic of other associations. In the field, small pockets of a dominant species such as gambel oak would appear to the field ecologist as a different association. However, on the aerial photos this pocket would occur in the transition area and be mapped as part of the complex. The low commission error of this type is likely a result of this confusion.


Navajo rock formations and riparian vegetation at ZION.

4. DISCUSSION

Zion National Park is an unique place with many spectacular landforms caused by massive geological uplift and erosion. This has led to a complex topography of benches, slopes, slot canyons, sheer cliffs, and isolated mesas that create new habitats and fragment many other habitats typical of the Colorado Plateau. During this project we found it very challenging to both classify and map the vegetation into meaningful context for all levels of interest (local, regional and national). However, with patience and persistence we feel that we were fairly successful as evidenced by the **42** new plant associations documented for ZION, the high level of detail (over 41,000 polygons), and the initial accuracy of more than 81%. Now that it is done, we are proud of our efforts and hope that they will be used and improved upon in the future.

–A few thoughts and suggestions:

4.1 Field Survey

In our opinion, the single most valuable asset in mapping vegetation is the field ecologist. Without a thorough detailed documentation of the vegetation on the ground no classification or map could be produced. Collecting plot data across rugged terrain is not easy and every effort should be made to find competent and energetic field crews with botanical and ecological backgrounds that can accomplish this task. Second, once hired, field crews should be adequately trained in both the project's methods and the local flora. Third, field crews should be supported logistically with housing, transportation, supplies, technical training, supplies, and equipment

In retrospect, smooth field survey work can be insured in part by following these recommendations:

- Job posting and hiring of competent field ecologists should begin as early in the project as possible.

Field crews should be hired and retained across multiple field seasons to maintain consistency and avoid re-training.

- Help with housing and transportation for field crews should be reviewed and addressed before the start of work especially for expensive or remote areas.

- Training should be thorough and include both Park specific issues such as access limitations, GPS specifications and program specific parameters such as plot set-up and data recording.

- Follow-up, oversight, and communication with the field crews should be maintained at all times. This includes regular updates/progress reports and meetings with all participants (photo interpreters, Park staff, and ecologists)

- Parks should be encouraged to take on as much of an active role as they can. This can include anything from the actual hiring of the crews as NPS seasonals, to providing housing, or just tagging along on a data collection trip.

Helicopter

One of the most daunting tasks was collecting plot data away from established roads and trails. Even after two full field seasons we did not get adequate distribution of sample plots. This was a direct result of the inaccessible nature of the Park. Literally some areas of ZION, such as isolated towers and slot canyons, proved impossible to traverse without technical climbing capabilities. This, coupled with other common hazards such as dehydration, heat exhaustion, and flash floods, caused the field crews to avoid large areas of the Park. Examining our options we felt that a short helicopter-assisted field session would be the safest and most economical solution. Although concerns were raised about impact to remote sites, in the end the helicopter proved to be a safe alternative for getting ecologists into the backcountry. Please see **Appendix G** for more details on the use of the helicopter at ZION.

4.2 NVC Classification

Once the data was collected it took a tremendous amount of time to classify the NVC plant associations. This was due in part to two contributing factors: lack of previous plant classification work in the area and a complex mix of vegetation. Future projects with a similar lack of information and a high level of diversity may want to increase the time to collect more data and postpone the mapping stage.

Global rarity

ZION is a very special and unique place with over 20 endemic plant taxa (Welsh 1995). Most of these endemic taxa are restricted to hanging gardens, which are an unusual but distinctive feature of the Park. Hanging gardens occur on sheer rock cliffs and are fed by water seeping out of more porous Navajo Sandstone where it overlays impervious rock layers. They were not addressed by this project due to their small and concealed nature and also because they have been well studied in the past (Malanson and Kay 1980, Malanson 1980, 1982, Welsh 1989).

Other than hanging gardens, relatively few vegetation types at Zion are considered globally rare or threatened. However not enough is known about many of these associations to evaluate their global rarity. Thirty-one of the 52 existing NVC associations found at ZION have not been assessed for their global rarity or endangerment, and none of the 42 new associations have been assessed. Thus global rarity or endangerment is not known for 73 of the 95 total plant associations documented by this study. It is likely some of the new plant associations are rare or threatened, but more vegetation survey is needed across the Colorado Plateau, Utah Mountains and Great Basin to develop a regional perspective.

Currently, we feel that the most threatened vegetation types at ZION are the riparian forests and the native dry grasslands. Multiple impacts from hydrological modification, historic overgrazing, recreation, interruption of ecological processes (such as fire suppression), and/or invasion of introduced species (especially the annual grasses such as *Bromus rigidus, B. rubens* and *B. tectorum)* all threaten these types. Based on these criteria, 3 plant associations to watch at ZION include:

Association Name	Element Code	Global Rank
Populus fremontii - Fraxinus velutina Woodland	(CEGL000942)	G2G3
Hesperostipa comata Great Basin Herbaceous Vegetation	(CEGL001705)	G2G4
Pleuraphis jamesii Herbaceous Vegetation	(CEGL001777)	G2G4

Additional survey work is needed to further define some of the remaining sparse vegetation types. Anthropogenic disturbance of many of the lowland riparian vegetation types created challenges in classifying them.

4.3 Aerial photos and Orthophotos

The acquisition of new orthophotos in addition to the aerial photography was critical to our mapping efforts at ZION. We found that these not only saved time in the digitizing and transfer stage but also aided tremendously with map verification. The true color orthophotos provided the utility of a map with the functionality of an aerial photo. In other words, we could easily prepare and plot draft maps that contained both our polygon outlines and a true color representation of the vegetation. In the past we would have had to either plot polygons on less-clear black-and-white orthophotos or use a clumsy combination of non-rectified aerial photos and simple color plots. Further, as a digital product they afforded us the capability of easily reproducing them for multiple users.

We would suggest that future projects strongly consider purchasing new orthophotos in addition to the aerial photography for the following reasons: 1.) Reduces the amount of time needed for digital transfer or digitizing of the line work; 2.) helps minimize shadows and scale distortion in areas with large changes in elevation; 3.) increases the accuracy and thoroughness of the mapping by having *recent,* true-color basemap imagery; 4.) allows for more useful and easier dissemination of draft products to field crews, mappers, ecologists, etc., and 5.) is a great stand alone product that can be used in many other applications.

4.4 Photo-interpretation and Map Units

Inherent to vegetation mapping projects is the need to produce both a consistent vegetation classification and a set of map units. Typically the systems are very similar if not identical, but when using a national classification such as the NVC there is typically not a strict one-to-one correspondence. This is due to the remote sensing nature of photographic interpretation and its ability to only delineate map units based on complex photo signatures. Subtle vegetation characteristics that can be seen on the ground are not necessarily the same as those apparent on the photos. Canopy closure, shadows, and timing of the photography can also distort or obscure photo signatures.

For a highly diverse park such as Zion we suggest that a completed (or nearly completed) classification be in place before the actual interpretation begins. This will avoid having to revisit or, worst case, redo the interpretation based on classification changes. Ideally, plot sampling should begin early in the project, followed by analysis of the vegetation data to the NVCS before the ground-truthing and interpretation of the aerial photographs. It is important to have a high level of confidence in the plant associations during photo interpretation so that vegetation types can be accurately related to the photo signatures. Also critical is deciding how to characterize and describe common types that are widely distributed but highly variable in species composition

To ensure effective mapping, more map verification or ground-truthing needs to occur at ZION. We feel that this project in many ways should be viewed as a cursory remote sensing effort that needs to be refined and periodically updated. To do this, GPS points, mapping, surveying, or new photo interpretation of the vegetation on the ground can greatly help improve the quality and accuracy of this project. Also since the photos represent just a snapshot in time, verification efforts should occur across the entire growing season to better describe seasonal variability.

4.5 Future Recommendations

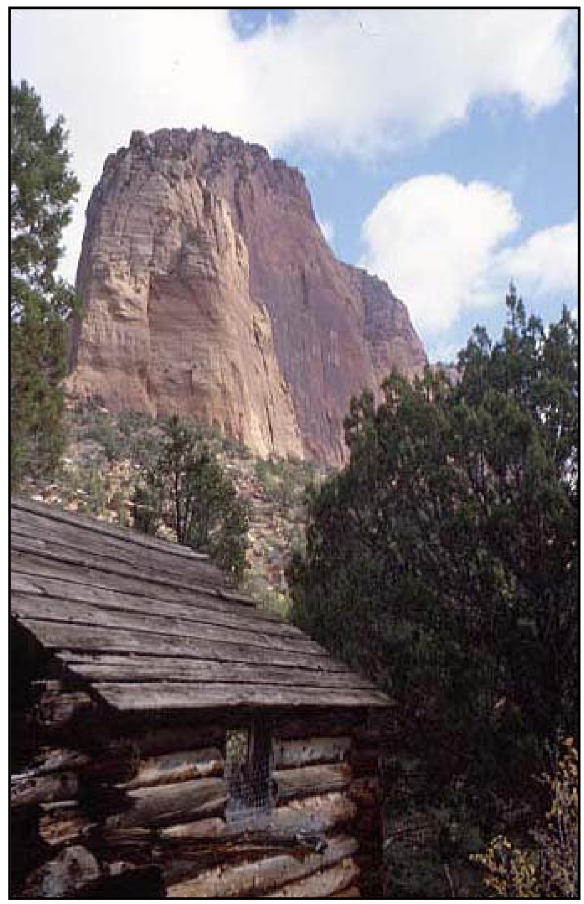
In summary, this project represents the best efforts put forth by one group of people over one relatively short period in time. In order to create the best possible "long-term" vegetation classification for ZION and the most accurate and detailed GIS layer, this project should be viewed as a place to start rather than an ending. In other words, present and future ZION staff should be encouraged to scruitinize this project, building from its strengths and fixing its limitations. By keeping in mind that this project was only a snapshot in time, future efforts can help complete our understanding of the vegetation at ZION and how it may change. We hope that the products presented here will help focus and tailor future efforts such as the following:

1. The high diversity of plant species and inaccessibility of the Park warrants periodic **field surveys** by experienced ecologists. In this way new plant associations could be discovered and existing types could be updated.

2. Remote sensing does not replace on-the-ground knowledge or hard GPS or survey-linked data. Time limitations curtailed the amount of **ground-truthing** done with the map. As opportunities arise, maps should be sent into the field to be verified by competent crews. Also GPS data and other GIS layers should be used to improve and update the spatial data. We feel strongly that this product should not be static but change with new and better information.

3. To better understand the limitations of the map, the **accuracy assessment** data presented in **Table 6** should be thoroughly reviewed by the Park. Map classes with low accuracy should be examined to see if they could be improved with future studies using ground-truthing or other remote-sensing formats (i.e. color infrared, hyperspectral, etc). Also, landscape modeling my help to tease out the location of specific types based on specific habitat information. Finally for some applications it may make sense to combine map classes into higher units, such as alliances or ecological systems to improve their accuracy**.**

For monitoring purposes, **change over time** could be addressed by similar remote sensing projects. New aerial photos or compatible digital imagery taken 5, 10, 20+ years from now would capture this change. This new imagery could then be used to create up-to-date vegetation layers and compare changes in both specific vegetation stands and across the entire Park.



5. BIBLIOGRAPHY

Anderson, J.R., E.E. Hardy, J.T. Roach, R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. *Geological Survey Professional Paper 964*. Washington, DC: U.S. Government Printing Office.

Austin, M.P. and P.C. Heyligers. 1989. Vegetation survey design for conservation: gradsect sampling of forests in northeastern New South Wales, Biological Conservation. **50**: 13-32.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science. **23**: 69-82.

Federal Geographic Data Committee. 1997. *FGDC Vegetation Classification and Information Standards*. Reston, VA.

Fowler, James Floyd. 1995. Biogeography of hanging gardens on the Colorado Plateau (diversity, species richness). Ph.D. dissertation, University of Wyoming. Laramie, WY. 209 p.

Gillison, A.N. and K.R.W. Brewer. 1985. The use of gradient directed transects of gradsects in natural resource survey. Journal of Environmental management. **20**:103-127.

Grossman, D.H., D. Faber-Langendoen, A.W. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. *International Classification of Ecological Communities: Terrestrial Vegetation of the United States. Volume I: The National Vegetation Classification Standard.* (Draft June 1997.) The Nature Conservancy, Arlington, VA.

Grossman, D.H., K.L. Goodin, Xiaojun Li, D. Faber-Langendoen, M. Anderson, P. Bourgeron, and R. Vaughn. 1994. Field methods for Vegetation Mapping. NBS/NPS Vegetation Mapping Program. The Nature Conservancy, Arlington, VA, and Environmental Systems Research Institute, Redlands, CA.

Hamilton, Wayne. 1995. *The Sculpturing of Zion.* Zion Natural History Association. Springdale, UT 132 pages.

Hill, M. O. 1979. Twinspan, a Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell Univ., Ithaca, NY. 90 p.

Hill, M. O., and H. G. Gauch, Jr. 1980. Detrended correspondence analysis: An improved ordination technique. Vegetatio. 42:47-58.

Kartesz, J. T. 1999. *A synonymized checklist and atlas with biological attributes for the vascular flora of the United States, Canada, and Greenland, First Edition,* In: J. T. Kartesz and C. A. Meacham. Synthesis of the North America Flora, Version 1.0. North Carolina Botanical Garden, Chapel Hill, N.C.

Malanson, G. P., and J. Kay. 1980. Flood frequency and the assemblage of dispersal types in hanging gardens of the Narrows, Zion National Park, Utah. Great Basin Naturalist 40(2):365-371.

Malanson, G. P. 1980. Habitat and plant distributions in hanging gardens of the Narrows, Zion National Park, Utah. Great Basin Naturalist 40(2):178-182.

Malanson, G. P. 1982. The assembly of hanging gardens: Effects of age, area, and location. American Naturalist 119:145-150.

McCune, B. and M.J. Mefford. 1997. PC-ORD*. Multivariate Analysis of Ecological Data, Version 3.0*. Gleneden Beach, OR: MjM Software Design

Moravec, J. 1993. Syntaxonomic and nomenclatural treatment of Scandinavian-type associations and associations. Journal of Vegetation Science 4:833-838.

Ter Braak, C. J. F. (1987-1992) CANOCO – a FORTRAN program for Canonical Community Ordination. CANOCO is an extension of Cornell Ecology program DECORANA (Hill,1979). Microcomputer Power. Ithaca, NY. P95

The Nature Conservancy. 1997. PLOTS Database System, Version 1.1. The Nature Conservancy, Arlington, VA.

The Nature Conservancy and Environmental Research Systems Institute. 1994a. *NBS/NPS Vegetation Mapping Program: Accuracy Assessment Procedures.* Arlington, VA.

_____. 1994b. *NBS/NPS Vegetation Mapping Program: Field Methods for Vegetation Mapping*. Arlington, VA.

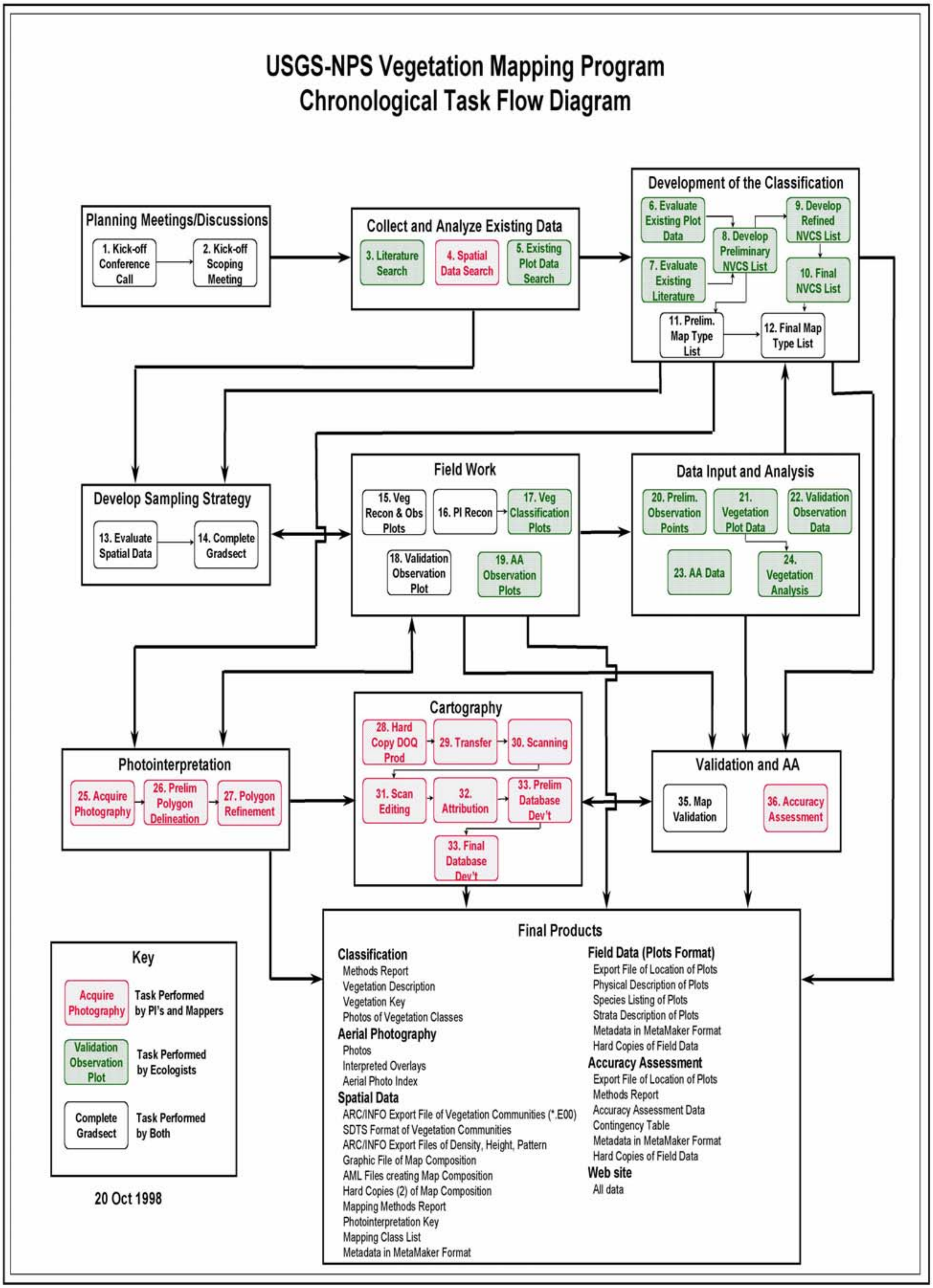
_____. 1994c. *NBS/NPS Vegetation Mapping Program: Standardized National Vegetation Classification System*. Arlington, VA.

Welsh, S.L. 1995. Rare plant survey of shuttle system and vascular plant scientific and common name list. Zion National Park annual report 1994-95. Unpublished report. Zion National Park. Utah. p28.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L.C. Higgins. 1993. *A Utah Flora, 2nd ed*. Brigham Young University Print Services, Provo, UT.

Welsh, S.L. 1989. On the distribution of Utah's hanging gardens. Great Basin Naturalist **49**(1):1-30.

APPENDIX A. Flowchart for the USGSNPS Vegetation Mapping Program


USGS-NPS Vegetation Mapping Program
Chronological Task Flow Diagram
Planning Meetings/Discussions
1. Kick-off Conference Call
2. Kick-off Scoping Meeting
Collect and Analyze Existing Data
3. Literature Search
4. Spatial Data Search
5. Existing Plot Data Search
Development of the Classification
6. Evaluate Existing Plot Data
7. Evaluate Existing Literature
8. Develop Preliminary NVCS List
9. Develop Refined NVCS List
10. Final NVCS List
11. Prelim. Map Type List
12. Final Map Type List
Develop Sampling Strategy
13. Evaluate Spatial Data
14. Complete Gradsect
Field Work
15. Veg Recon & Obs Plots
16. PI Recon
17. Veg Classification Plots
18. Validation Observation Plot
19. AA Observation Plots
Data Input and Analysis
20. Prelim. Observation Points
21. Vegetation Plot Data
22. Validation Observation Data
23. AA Data
24. Vegetation Analysis
Cartography
28. Hard Copy DOQ Prod
29. Transfer
30. Scanning
31. Scan Editing
32. Attribution
33. Prelim Database Dev't
33. Final Database Dev't
Photointerpretation
25. Acquire Photography
26. Prelim Polygon Delineation
27. Polygon Refinement
Validation and AA
35. Map Validation
36. Accuracy Assessment
Key
Acquire Photography
Task Performed by PI's and Mappers
Validation Observation Plot
Task Performed by Ecologists
Complete Gradsect
Task Performed by Both
20 Oct 1998
Final Products
Classification
Methods Report
Vegetation Description
Vegetation Key
Photos of Vegetation Classes
Aerial Photography
Photos
Interpreted Overlays
Aerial Photo Index
Spatial Data
ARC/INFO Export File of Vegetation Communities (*.E00)
SDTS Format of Vegetation Communities
ARC/INFO Export Files of Density, Height, Pattern
Graphic File of Map Composition
AML Files creating Map Composition
Hard Copies (2) of Map Composition
Mapping Methods Report
Photointerpretation Key
Mapping Class List
Metadata in MetaMaker Format
Field Data (Plots Format)
Export File of Location of Plots
Physical Description of Plots
Species Listing of Plots
Strata Description of Plots
Metadata in MetaMaker Format
Hard Copies of Field Data
Accuracy Assessment
Export File of Location of Plots
Methods Report
Accuracy Assessment Data
Contingency Table
Metadata in MetaMaker Format
Hard Copies of Field Data
Web site
All data

APPENDIX B: Sampling Design: Modified Stratified Random

Zion National Park Sample Site Selection Methodology
Written By Michael Schindel

BACKGROUND

A modified Gradsect analysis procedure was developed for the Yosemite National Park vegetation mapping project as a tool to aid field crews in visiting as many of the different environments as possible to sample the diversity of vegetation in the park (Schindel 1999 unpublished report). The theory behind the Gradsect methodology is that if field crews visit the full spectrum of physical environments, then most of the vegetation types will be sampled. To do this ecologists select a set of key abiotic factors that influence vegetation diversity. A practical constraint for this project (Zion NP) was that neither time nor money was available to develop new digital data so we were limited to existing data layers or those that could be developed relatively quickly.

METHODS

The Zion National Park fieldwork site selection was largely based on concepts of gradsect (Gradient- Directed Transects) analysis. Gradsect analysis focuses on the key abiotic factors that influence a region's vegetative diversity. The four physical factors used for the Zion modified gradsect model were geology, solar insolation, hydrology, and fire history. Each of these 4 variables was broken into logical classes. We used perennial streams and divided the region into hydric and upland classes. A 40 year fire history map provided by the Park was used to identify recently burned areas. The solar values were based upon an annual solar budget model derived from the 30 m DEM and solar ephemeris values calculated by the Jet Propulsion Laboratory's Ephemeris Generator. The geologic layers were classified on the basis of similar chemistry and vegetation response. Volcanic rocks were broken into 3 elevation classes because they are the only non-sedimentary rocks and aren't confined to any particular stratum. Elevation was otherwise not modeled because the sedimentary geology divides the park into nearly perfect horizontal classes.

The 4 resulting maps were then combined to generate a grid of all the possible combinations of these factors. Each unique combination represented a Biophysical Unit (BPU). There were 70 BPU types within the Park boundary forming a mosaic of 18000 polygons.

BPU Key

1000-Hydric	100-Burned	10-Full Shade	1-Alluvium
2000-Uplands	200-Unburned	20-Partial Sun	2-Carmel
		30-Partial Shade	3-Chinle/Moenkopi/Kaibab
		40-Full Sun	4-Slide/Kayenta/Moemave
			5-Dakota
			6-Navajo/Temple Cap
			7-Volcanics 3600-5300 ft.
			8-Volcanics 5301-7000 ft.
			9-Volcanics 7001-Summit

Field Survey Site Selection

A subset of BPU polygons was selected for field visits using cost surface analysis. The Zion cost surface model was based upon the slope calculation (in degrees) of the 30 meter DEM. Cells containing perennial streams and steep slopes (> 45 degrees) were reclassified as "No Data". These cells were considered barriers in subsequent cost-path analysis. The remaining cells were valued according to their slope, except roads, trails and routes, which were reclassified as 1, 2 and 3 respectively. A Cost Distance function was performed to calculate the cumulative cost of travelling to any 30 meter cell in the park from the nearest road. The centroid of each BPU was then joined to its associated cost value. The cost, acreage and *x, y* coordinates of each BPU were then used to select 2-3 polygons of every type that were accessible, of reasonable size, and stratified geographically. Polygons ranged in size from .18-110 hectares, with most between 1-10 hectares. The smallest polygons in this group represented BPU types that only occurred as small patches. Riparian BPUs, for example, tend to be small because they are often confined to narrow, meandering settings. BPUs with only one or two occurrences also were selected regardless of size or cost.

Six, 1:24000 scale maps were produced for the field crews showing the selected BPU polygons with USGS Digital Raster Graphes (DRG) as backdrops. These maps covered the entire park. A table was included on each map containing the *x y* coordinates for each selected BPU to assist with navigation. These maps and supporting documentation were sent to the field leader prior to the field season.

Results

The field crew sampled 91 plots during the 1999 field season. 46 of those plots were on or within 100 meters of the selected BPU polygons. Most of the remaining samples were taken en route to a BPU polygon. A diverse assemblage of vegetation types was captured during the 1999 sampling effort. The modified gradsect analysis selected a good approximation of the range of physical habitats present within the park. It will be interesting to compare this initial selection of BPUs to the final vegetation map to see exactly how many types would be captured if each of the 170 BPU polygons in this set had been visited and inventoried.

Analysis for the 2000 Field Season

For the 2000 field season this approach was modified. Photo Interpretation had begun after the 1999 sampling season and the interpreters needed information on specific sites they couldn't identify. The narrow selection of potential samples was abandoned in order to allow the field crews to work anywhere in the park in response to the interpreters questions. Two analyses were used to select the season's samples. The first was a neighborhood analysis on the full BPU set. This analysis measured the diversity of BPU types within a 1 kilometer radius. Three areas were identified with exceptional BPU diversity. Previous studies have shown that steep environmental gradients correlate with a high diversity of vegetation types. All the polygons from these 3 regions were included in the final data set.

The second analysis began with the full BPU set merged by type. In other words, all polygons of type "1261" throughout the entire park were considered part of the same super polygon. This data set was intersected with the 1999 field work. All types that had received a sample that year were removed from the set. Polygons less than 0.18 ha. were also removed. The remaining polygons were left as potential sample sites.

The union of these two analyses yielded a mosaic of 2,121 polygons scattered across the park; heavily weighted towards types that hadn't yet been sampled. As the sampling and photo interpretation proceeded, the field crews were able to accommodate requests from the photo interpreters while sampling other types in the vicinity. Field crews were responsible for keeping track of the polygons to insure that too many samples were not collected from any one BPU or vegetation type. At least one of the 3 high diversity areas was also thoroughly investigated regardless of the BPU types.

APPENDIX C: Field Methods Manual

SAMPLING AT ZION NATIONAL PARK
A Basic Guide for Field Work
Modified for the 2000 Field Season, USGS/NPS Vegetation Mapping Program

This document is intended to give you general instructions and guidelines for conducting your field work at Zion National Park. Detailed, field-by-field coding conventions for the primary form you'll be completing in the field (the Plot Survey form) are provided in the 'cheat sheet' (**Appendix D**).

<u>Overview</u>
The data that you collect in Zion this year will be combined with data collected in 1999 and used to create a relatively fine-scale delineation of vegetation pattern in Zion National Park and its environs. The range of habitats, and the corresponding diversity of vegetation types, found here is complex. The understanding of finer-scale, ecologically distinct vegetation types that you will help create may be used by the Park to plan appropriate management activities, monitor the results of these activities, track long-term changes in vegetation, direct searches for rare species, model fire behavior, and portray the wealth of natural diversity on Park lands to the public.

Establishing a field sampling strategy that captures—in only two field seasons—sufficient data on all the distinct vegetation types in an area as large, diverse, and rugged as Zion is an ongoing challenge. To make the sampling as efficient as possible, the key environmental variables thought to be driving vegetation pattern were identified. These included factors such as geology, solar insolation, hydrology, and fire history (see TNC 1998). The geographic locations of various classes of these environmental factors were then overlaid and areas with unique combinations (called biophysical units or BPUs) were mapped. The basic idea being that by identifying and placing samples in the range of BPUs we would be likely to sample the range of vegetation types. During the first sampling season, wherever possible, areas with clusters of these different BPUs in close proximity to each other *and* in close proximity to roads and trails were located, so that getting to these places could be as easy as possible. In 2000, we will be putting more emphasis on sampling the diversity of environmental conditions and access will be a secondary factor in sampling selection.

As much as possible, photo interpreters will be examining aerial photos of the areas identified by the BPUs and will make an educated guess about what types of vegetation will be found in the unsampled BPUs using plot information from the sampled ones. The photo interpreters will supply Mylar overlays with polygons delineated and labeled with vegetation types. The vegetation "types" they are using to tag their polygons are those included in the preliminary classification of Park vegetation created using the U.S. National Vegetation Classification system (Grossman et al. 1998).

During the second field season, some interpreted overlays attached to the photo prints will be available to help find the vegetation types to sample. The delineated polygons provide a perspective of accessibility to selected points and also indicate the size of homogenous stands so that sampling can be placed to best advantage within the types. The photo interpreters will give the selected, delineated polygons labeled with U.S. National Vegetation Classification types to the field crew, who will be keeping a running tally of the number of plots that still need to be established and sampled for each type.

The field crew will evaluate the field data, assign a preliminary vegetation type, and update the tally of vegetation types by number of plots still needed. The goal is to use *your* time as efficiently as possible; we are trying our best to avoid over-sampling of some types and under-sampling of others. Deciding where to sample to capture the full range of diversity over the Park is going to be very much an iterative process as the field season goes along!

Getting There
You will have a Digital Ortho Quarter Quad (DOQQ) with the BPUs you are to sample indicated. You and your partner will navigate towards each selected BPU using your road and trail maps, the DOQQ, and/or GPS. The DOQQ's will have roads and trails highlighted on them to help you as well.

Before you leave... check that you have all the materials needed to complete your fieldwork (Please see the checklist and "considerations for mission planning" in **Appendix D** to help you).

Every single morning... check your GPS receiver to make sure it is set to NAD 83.

Along the way...look around. Digital data layers are great, but they do ***not*** replace human perception. The goal of this field work is to sample all the different vegetation types that occur at Zion. If, on the way to one vegetation type, you see an assemblage of plants that seems unique and that is not included on the list of vegetation types, please sample if time allows. At Zion these undescribed vegetation types are more likely herbaceous or shrublands. You will be better able to recognize these undescribed vegetation types as the season progresses and you become more familiar with the vegetation types and how they can look on the ground.

Once There
Establishing a Plot
1) Figure out where to place your plot. This is a subjective process. You'll want to place your plots in areas that seem to be both relatively **homogenous** and **representative** of the vegetation of the polygon as a whole. In other words, avoid areas where the vegetation appears to be transitioning from one type to another and areas with anomalous or heterogeneous structure or species composition. Take some time to do this carefully, because some of the plots you set up may be *permanent*; relocated and resampled over time in order to determine responses to management and other useful things. Look at *all* the vegetation strata to determine if the area is structurally and floristically uniform and generally try to place your plots at least 30 m from what you see as the 'boundary' between this vegetation type and any neighboring, distinctly different types. During the training period this step will be emphasized and discussed in detail. However, the rule-of-thumb is to conduct a reconnaissance of the plot if time and topography allows.

Note: In cases where a polygon is very heterogeneous, more than one plot may be needed. Again, look around, use that human perception.

The first plot in each type will be permanent. Drive rebar or some other steel marker flush with ground with a rock or hammer in the approximate center of the plot. If you are unable to place a marker in the center (e.g., slickrock), clearly describe on the form where it is in relation to the plot center e.g., 3.5 m @200 degrees from plot center. Details of marking need to be arranged with the Park.

3) Using your GPS receiver, record the UTM in the center of the plot under the **Field UTM X** and **Field UTM Y** on the field form. Remember that this is about to become a permanent plot, so being able to *find* it again will be key: use the GPS, rather than estimating. Also mark and label the location of the plot on a USGS 7.5 min. topographic map. If you cannot get a GPS reading, estimate UTMs from the USGS topographic map and note on the form that you had to resort to this method. Plot may be circular, rectangle or square. Note shape and dimensions on the field form. If the plot is rectangle or square, record the azimuth of the long side (any side if square) to help relocate the plot. It may make more sense to establish rectangular plots in linear vegetation types (e.g. riparian or ridgeline types). Standard plot sizes should be as follows:

If you're in a ...	**You should usually make your plot...**	**Giving you a plot area of...**
Forest (i.e., trees have their crowns overlapping, usually forming 60-100% cover)	11.3 m radius OR 20 m x 20 m	400 m^2 400 m^2
Woodland (i.e., open stands of trees with crowns usually not touching. Canopy tree cover is 25-60% Or exceeds shrub, dwarf-shrub, herb, and nonvascular cover).	11.3 m radius OR 20 m x 20 m	400 m^2 400 m^2
Shrubland (i.e., shrubs greater than 0.5 m tall are dominant, usually forming more than 25% cover OR exceeding tree, dwarf-shrub, herb, and nonvascular cover)	11.3 m radius OR 20 m x 20 m	400 m^2 400 m^2
Dwarf-shrubland (heath) (i.e., Shrubs less than 0.5 m tall are dominant, usually forming more than 25% cover OR exceeding tree, shrub, herb, and nonvascular cover).	5.65 m radius OR 10 m x 10 m	100 m^2 100 m^2
Herbaceous (i.e., Herbs dominant, usually forming more than 25 percent cover OR exceeding tree, shrub, dwarf-shrub, and nonvascular cover).	5.65 m radius OR 10 m x 10 m	100 m^2 100 m^2
Nonvascular (i.e., nonvascular cover dominant, usually forming more than 25% cover).	2.82 m radius OR 5 m x 5 m	25 m^2 25 m^2

Note: You can deviate from the standard plot *shapes* where that makes sense, but the total plot *area* encompassed by the boundaries should be as listed above for each major class of vegetation. For example, forested riparian vegetation, may be sampled in a more linear 10 x 40 m (400 m^2) plot; herbaceous riparian or ridgeline vegetation in a 2 x 50 m (100 m^2) plot. You may also increase the size of the plot to the next standard size if necessary to sample the heterogeneity of the vegetation. Forests, woodlands and shrublands can be increased to 1000 m^2. Please make a note on plot form.

4) Once the plot is established, it is generally a good time to fill out the **Identifiers/Locators** part of your Plot Survey Form (**Appendix D**) and take the plot photos.

Taking photographs
Two color slide photos will be taken of each plot. The purpose is to get a good representation of the vegetation of the plot, not individual species. A piece of paper (or a chalk board or dry erase board) should be placed in the plot, with the plot number recorded on it, so that the photo includes the plot number. Preprinted plot numbers could be made, printed or copied onto colored paper (white has such strong contrast as to be unreadable in the photo) and attached to the back of a clipboard. This may save time in the field by not having to write plot numbers.

Take the photograph looking across the contour if plot is steep. Work out a standard direction for gentle and flat plots with Park personnel. Flag or mark plot marker for photo if plot is permanent to aid relocation. Record roll #, frame # and azimuth on plot form. Crew Leader is responsible for labeling and organizing slides. One entire set of 35-mm slides will be provided to both the Park and to the USGS. Digital scanned copies will also be available on the final report CD-Rom.

<u>Data Collection</u>
Environmental Description
See the coding instructions at the end of this document for guidance on the specific fields.

Vegetation Description
For guidance on the specific fields on the second page of the form, see the coding instructions.
As you begin to collect the species, DBH, and cover information, keep these rules in mind—they will speed your data collection considerably:

1) Except in very diverse plots, don't spend more than **20 minutes** looking for new and different species to record. Remember that these plot data are to be used to classify the overall vegetation of the Park, not to make a complete species list for it. And if you had to spend much more than 20 minutes to find a species, it probably isn't going to be important in characterizing the vegetation type. For diverse plots with over 25 taxa you may take up to 30 minutes on the listing process.

2) If you can't identify a plant to species, record it on your form as "unknown species 1," "unknown species 2," "Carex unknown sp. 1," etc. Record associated cover class and other data for the unknown as you would for any other species. Then do one of two things:

If you need the species identified right away because it appears to be dominant or diagnostic (you're seeing it all over the place or you're seeing much more in this particular vegetation type than in others), take a sample of the species with as much of the plant as possible, especially intact sexual parts, if present. Place the sample in a baggie, and label the baggie (or specimen) with the plot code and the name you gave it on the data form.

If you don't need the plant keyed right away, press it. Mark the pressed specimen with the plot code and the name you gave it on the data form.

Please store your plant specimens in a cool, dry place. Bagged specimens will keep fresh longer in the refrigerator or ice chest until pressed or identified. You can, of course, key some of these out yourself if you want to, but don't let plant keying get in the way of your primary responsibility: field data collection. No one expects you to identify every plant but you should make an effort to learn at least the common species that keep recurring in plots. A quick prioritization of what to key and what to press may be made based on the recurrence of the species in samples and on the cover-class estimate of the species in a particular plot. If the species has a high cover value (>1%) it is more of a priority to identify. Field crews should mark the specimen tag with its cover class estimate as well as its unique identifying number for the vegetation sample. If pressed specimens begin to build up, let TNC folks know. They can take steps to have some of them identified.

Observation Point Form
Occasionally, you will need to collect some plot-free data. This will happen when:
1) The photo interpreters can't tell what kind of vegetation is in a particular polygon [as noted on the Mylar] or
2) The photo interpreters were wrong about what kind of vegetation is in a polygon and sufficient plot data has already been collected for the kind of vegetation that is actually there.

In these two cases, there is no need to establish a plot. However, you will help the photo interpreters identify this type in the future if you collect some data. You will navigate to the polygon as usual, scout out the polygon briefly to get a feel for what it is like, and record some general data to characterize it on an Accuracy Assessment Point form. This is an abbreviated version of the Plot Survey form, and the same cheat sheet can be used to help with filling it out. GPS points may be taken at any part of the polygon as long as it is >30 m from its edge, to verify its location.

We hope you find your field season at Zion enjoyable and rewarding. Best of luck!

LITERATURE CITED

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I. The National Vegetation Classification System: development, status, and applications. The Nature Conservancy, Arlington, Virginia.

The Nature Conservancy [TNC]. 1998. An environmentally-driven approach to vegetation sampling and mapping at Yosemite National Park. Report prepared for the U.S. Department of the Interior, National Biological Survey and National Park Service. The Nature Conservancy, Arlington, Virginia.

APPENDIX D: Observation, Plot, and AA Field Forms and Instructions

NATIONAL PARK VEGETATION MAPPING PROGRAM: OBSERVATION POINT FORM (1997)

IDENTIFIERS/LOCATORS

Plot Code________________________ Polygon Code________________________

Provisional Community Name____

State ___ Park Name ________________________ Park Site Name ________________

Quad Name________________________________ Quad Code________________

GPS file name____________ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N

please do not complete the following information when in the field
Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone__________

Survey Date__________ Surveyors____

ENVIRONMENTAL DESCRIPTION

Elevation ______________ Slope ______________ Aspect______________

Topographic Position

Landform

Cowardian System	Hydrologic Regime		Salinity Modifiers
___Upland ___Riverine ___Palustrine ___Lacustrine	Non-Tidal ___Permanently Flooded ___Semipermanetly Flooded ___Seasonally Flooded	___Saturated ___Temporarily Flooded/Saturated ___Intermittently Flooded	___Saltwater ___Brackish ___Freshwater

Environmental Comments:	Unvegetated Surface: (please use the cover scale below)
	___ Bedrock ___ Litter, duff ___ Wood (> 1 cm) ___ Large rocks (cobbles, boulders > 10 cm) ___ Small rocks (gravel, 0.2-10 cm) ___ Sand (0.1-2 mm) ___ Bare soil ___ Other:________________________

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata & Unvegetated Surface	Height Scale for Strata
Trees and Shrubs ___Evergreen ___Cold-deciduous ___Drought-deciduous ___Mixed evergreen - cold-deciduous ___Mixed evergreen - drought-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Mixed broad-leaved/Needle leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01 5% 02 10% 03 20% 04 30% 05 40% 06 50% 07 60% 08 70% 09 80% 10 90% 11 100%	01 <0.5 m 02 0.5-1m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35 - 50 m 10 >50 m

Strata	Height	Cover Class	Dominant species (mark any known diagnostic species with a *)	Cover Class
T1 Emergent	_____	_____		
T2 Canopy	_____	_____		
T3 Sub-canopy	_____	_____		
S1 Tall shrub	_____	_____		
S2 Short Shrub	_____	_____		
S3 Dwarf-shrub H Herbaceous	_____	_____		
N Non-vascular	_____	_____		
V Vine/liana	_____	_____		
E Epiphyte	_____	_____		

please see the table on the previous page for height and cover scales for strata

Other Comments

Cover Scale for Species

01	<1%
02	1-5%
03	5-25%
04	25-50%
05	50-75%
06	75-100%

NATIONAL PARK VEGETATION MAPPING PROGRAM: PLOT SURVEY FORM

IDENTIFIERS/LOCATORS

Plot Code__________________________ Habitat/BPU Code__________________________

Provisional Community Name__________________________

State ___ Park Name__________________ Park Site Name__________________________

Quad Name__________________________ Quad Code__________________________

GPS file name________________ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N
Comments: __________________________ Error +/- ___ ____ m
Please do not complete the following information when in the field
Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone ____________

Survey Date_____________________ Surveyors__________________________

Directions to Plot

Plot length(m)______ Azimuth ______ Plot width(m)_____ If circle (diam)_____ Plot Photos (y/n) __ Roll # _____ Frame # ____________

Plot Permanent (y/n) ____ Comments on photos or marker

Plot representativeness (discuss decisions for placement and/or reasons for non-representativeness)

a. Representativeness of association (if known):

b. Representativeness of plot in stand:

ENVIRONMENTAL DESCRIPTION

Elevation ____________________ Slope _____________________ Aspect_________________________

Topographic Position (see cheat sheet)

Landform (see cheat sheet)

Surficial Geology (see cheat sheet)

Cowardian System
___ Upland ____ Palustrine
____ Riverine ____ Lacustrine

Hydrology
___Permanently Flooded ___Seasonally Flooded ___Temporarily Flooded
___Semipermanetly Flooded ___Saturated ___Intermittently Flooded
___Unknown

Environmental Comments (dynamic stage, fire history, insect damage, etc):

Ground Cover: *(please estimate to the nearest percentage. Sum = 100%)*
___ Bare soil ___ Litter / duff ___ Wood (> 1 cm)
___ Bedrock ___Large rocks (cobbles, boulders > 10 cm)
___ Small rocks (gravel, 0.2-10 cm) ___ Sand (0.1-2 mm) dune /alluvium
___ Moss ___ Lichen ___ Cryptogam ___ Water ___ Other (name):

Soil Texture:
___ sand ___ loamy sand ___ sandy loam ___ loam
___ silt loam ___ silt ___ clay loam ___ silty clay
___ sandy clay ___ clay ___ peat ___ muck

Soil Drainage
___ Rapidly drained ___ Well drained
___ Moderately well drained ___ Somewhat poorly drained
___ Poorly drained ___ Very poorly drained

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata	Height Scale for Strata
Trees and Shrubs __Evergreen __Cold-deciduous __Mixed evergreen-cold-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	T 0-1% P >1-5% 1 >5-15% 2 >15-25% 3 >25-35% 4 >35-45% 5 >45-55% 6 >55-65% 7 >65-75% 8 >75-85% 9 >85-95% 10 > 95%	01 <0.5 m 02 0.5-1m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35 – 50 m 10 >50 m

	Height/Strata Class	Cover Class	Dominant Species (mark Diagnostics with *)
T1 Emergent	_______	_______	______________________________
T2 Canopy	_______	_______	______________________________
T3 Sub-canopy	_______	_______	______________________________
S1 Tall shrub	______	_______	______________________________
S2 Short Shrub	_______	_______	______________________________
S3 Dwarf-shrub	______	_______	______________________________
Ht Herbaceous	_______	_______	______________________________
H1 Graminoids	_______	_______	______________________________
H2 Forbs	_______	_______	______________________________
H3 Ferns	_______	_______	______________________________
H4 Tree seedlings	______	_______	______________________________
N Non-vascular	_______	________	______________________________
V Vine/liana	_______	________	______________________________
E Epiphyt	________	________	______________________________

Animal Use Evidence (including scat, browse, graze, burrows, bedding sites, etc)

Natural and Anthropogenic Disturbance Comments (please see cheat sheet for impact codes, list intensity as High, Med, or Low)

Other Comments (locations of photos and permanent plot marker)

Plot Code____

Species/percent cover: Starting with the uppermost stratum, list all species with % cover for each species in the stratum. For each tree species estimate seedling, sapling, mature and total cover indicating stratum . Also for forests and woodlands, on a separate page **or** line below each tree species, list the DBH of all trees above 5 cm diameter. Separate measurements with a comma (note if measurements are from multi-stemmed tree). Put an asterisk next to any species that are known diagnostics for a particular community in the classification. **Also list species outside the plot at the end of the table or designate with a 0 in Cover Class column.**

Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class	Stratum	Species Name	Cover Class

Cover Class Scale

T = >0-1%	5 = >45-55%
P = >1-5%	6 = >55-65%
1 = >5-15%	7 = >65-75%
2 = >15-25%	8 = >75-85%
3 = >25-35%	9 = >85-95%
4 = >35-45%	10 = >95%

Tree D.B.H Form

Plot Code:________________________________ Units in cm or inches (circle one)

Record tree diameter over 5 cm at 4.5 feet (1.37 m) height for species that contribute to tree canopy.

Separate measurements of multi-stemmed trees with commas. Can estimate by 5 cm dia. classes

Species	D.B.H.(s) for multi-stems trees

Species	D.B.H.(s) for multi-stems trees

Instructions for filling out Fields in the PLOT SURVEY FORM

Plot Survey Form
Plot Code
Code indicating the specific plot within the vegetation polygon. For the 2000 field season, the codes will be "ZION.XXX". Begin with ZION.101 and go from there. If another team is working, decide with them which plot numbers each team will use to identify the data they gather. For example, if a second team is working one week and approximately 100 plots have already been collected, they may get plots ZION.200 through ZION.215.

BPU Code
The biophysical unit identified—will be taken from the map. This is a less important field this year and can be filled in based on a post processing of GIS data from the GIS analysts.

Provisional Community Name
Using the provisional classification of the Park with which you've been provided, assign the name of the vegetation type which most closely resembles this type. Enter the finest level of the classification possible. In fact, none of the names may be a good fit; you may have found a new type. If that is the case, create a provisional name with the dominant and diagnostic species. The 'provisional community name' that is assigned will be used to update the tally of types x number of plots needed.

State UT

Park Name ZION NP

Park Site Name
Provisional name assigned by field worker that describes where the data were collected. It should represent an identifiable feature on a topographic map.

Quad Name
Appropriate name/scale from survey map used; use 7.5-minute quadrangle if possible.

Quad Code
Code of quadrangle map.

Field UTM X
Use GPS if at all possible. If you can't get a GPS reading, estimate coordinates from a topo map and note on the form that this method was used.

Field UTM Y
Use GPS if at all possible. If you can't get a GPS reading, estimate coordinates from a topo map and note on the form that this method was used.

GPS Error
Note the error in the GPS reading off the PLGR.

Survey Date
Date the survey was taken; year, month, day.

Surveyors
Names of surveyors, with principal surveyor (usually the Lead Ecologist) listed first.

Directions to Plot
Precise directions to the site using a landmark (e.g., a named point on the topo map, a major highway, using park naming conventions for roads) readily locatable on a 7.5 minute topo map as the starting point. Use clear sentences that will be understandable to someone who is unfamiliar with the area and has only your directions to follow. Give distances as closely as possible to the 0.1 mile and use compass directions. Give additional directions to the plot within the site. Do not take more than a couple of minutes to fill this out.

Plot Length and Plot Width
Enter diameter for circular plots and width and length dimensions for square or rectangular plots. Choose the appropriate plot size based on the following:

Vegetation Class	Standard Plot Dimensions	PLOT AREA
Forest	11.3 m radius or 20 m x 20 m	**400 m^2**
Woodland	11.3 m radius or 20 m x 20 m	**400 m^2**
Shrubland	11.3 m radius or 20 m x 20 m	**400 m^2**
Dwarf-shrubland	5.65 m radius or 10 m x 10 m	**100 m^2**
Herbaceous	5.65 m radius or 10 m x 10 m	**100 m^2**
Nonvascular	2.82 m radius or 5 m x 5 m	**25 m^2**

Plot Photos/ Roll Number/Frame Numbers
Indicate (Y or N) if photos of the plot have been taken at the time of sampling, and the roll and frame numbers of any photos. Also record azimuth of photo if not taken in standard direction.

Plot Permanent
Check off that the plot has been permanently marked.

Plot Representativeness
Does this plot represent the full variability of the polygon? If not, were additional plots taken? Note additional species not seen in the plot in the space provided below. Note: we distinguish in this section the plot's ability to represent the stand or polygon you are sampling as one component and the ability of this sample to represent the range of variability of the association in the entire mapping area. The former comment may be ascertained by reconnaissance of the stand. The latter comment comes only after some familiarity with the vegetation type throughout the mapping area and may be left blank if you have no opinion at this time.

ENVIRONMENTAL DESCRIPTION

Elevation
Elevation of the plot. **Specify whether in feet or meters** (this will depend on the units used on the GPS or on the topographic map being used). In general, we have determined that the reading you get from a topo map, provided you are certain where you are, is more accurate than the average reading from the GPS unit. Thus, please attempt to estimate your elevation with the topo map.

Slope
Measure the slope in **degrees** using a clinometer.
Aspect
Measure the slope aspect using a compass (be sure to correct for the magnetic declination). Note: all compasses should be pre-set to an average declination for the park and thus, readings from the compasses carried by the field crews may be directly noted.

Topographic Position
Topographic position of the plot. Choose one:

INTERFLUVE (crest, summit, ridge). Linear top of ridge, hill, or mountain; the elevated area between two fluves (drainages) that sheds water to the drainage channels.

HIGH SLOPE (shoulder slope, upper slope, convex creep slope). Geomorphic component that forms the uppermost inclined surface at the top of a slope. Includes the transition zone from backslope to summit. Surface is dominantly convex in profile and erosional in origin.

HIGH LEVEL (mesa). Level top of a plateau.

MIDSLOPE (transportational midslope, middle slope). Intermediate slope position.

BACKSLOPE (dipslope). Subset of midslopes that are steep, linear, and may include cliff segments (fall faces).

STEP IN SLOPE (ledge, terracette). Nearly level shelf interrupting a steep slope, rock wall, or cliff face.

LOWSLOPE (lower slope, foot slope, colluvial footslope). Inner gently inclined surface at the base of a slope. Surface profile is generally concave and a transition between midslope or backslope, and toeslope.

TOESLOPE (alluvial toeslope). Outermost gently inclined surface at base of a slope. In profile, commonly gentle and linear and characterized by alluvial deposition.

LOW LEVEL (terrace). Valley floor or shoreline representing the former position of an alluvial plain, lake, or shore.

CHANNEL WALL (bank). Sloping side of a channel.

CHANNEL BED (narrow valley bottom, gully, arroyo, wash). Bed of single or braided watercourse commonly barren of vegetation and formed of modern alluvium.

BASIN FLOOR (depression). Nearly level to gently sloping, bottom surface of a basin.

Landform

Enter the landform that describes the site where the plot was taken. Note on the code sheet the landform choices are listed at different scales. Thus, one can select more than one for plot if appropriate (e.g., mountain could be macro and ridge could be meso scale). You can develop your own list for Zion. Just be consistent so we can analyze by landform.

arroyo	lowland
alluvial fan	mid slope
alluvial flat	mountain
alluvial terrace	mud flat
bajada	noseslope
bank	piedmont
basin	plain
bench	plateau
butte	ravine
channel	ridge
cinder cone	rim
cliff	rock fall avalanche
colluvial slope	saddle
debris slide	seep
depression	shoreline
drainage	sinkhole (undifferentiated)
drainage channel (undifferentiated)	slide
dune (undifferentiated)	slope
escarpment	slough
flood plain	soil creep slope
foothills	stream terrace (undifferentiated)
gap	streambed
gorge	swale
hills	talus
hogback	toe slope
interfluve	valley floor
lake	wash

Surficial Geology

Note the geologic substrate influencing the plant community (bedrock or surficial materials). Accurately recording the geology at the plot is especially important if the plot is on an inclusion in the type on the geology map. The list below provides types from the Zion NP Geology Map.

<u>Zion NP Geology Map Units</u>
Alluvium
Alluvium Remnants
Carmel Formation
Chinle Formation
Dakota Formation
Kaibab Formation
Kayenta Formation
Lake and Pond Deposits
Lake Deposits
Moenave Formation
Moenkopi Formation
Navajo Sandstone
Slide Deposits
Slide Deposits – Calcite
Temple Cap Formation
Volcanic Rocks
Volcanic Rocks - Tephra

Gradsect lumped types (use these if you cannot determine the Zion Geology Map type)
Alluvium (except slide deposits)
Sandstones (Navajo and Temple Cap)
Limestone (Carmel formation)
Sandstone/shale (Kayenta, Moenave, and slide formations)
Shale and gypsum (Chinle and Moenkopi Formations)

The Sedimentary Geology of Zion from http://www.aqd.nps.gov/grd/parks/zion/#relsites

Rock Layer	Appearance	Where To See	Deposition	Rock Type
Dakota Formation	cliffs	top of Horse Ranch Mountain	streams	conglomerate and sandstone
Carmel Formation	cliffs	Mt. Carmel Junction	shallow sea and coastal desert	limestone, sandstone and gypsum
Temple Cap Formation	cliffs	top of West Temple	desert	sandstone
Navajo Sandstone	steep cliffs 1,600-2,200' thick red lower layers are colored by iron oxides tall cliffs of Zion Canyon;	Highest exposure is West Temple and Checkerboard Mesa	desert sand dunes covered150,000 square miles shifting winds during deposition created cross-bedding	sandstone
Kayenta Formation	rocky slopes	throughout canyon	streams	siltstone and sandstone
Moenave Formation	slopes and ledges	lower red cliffs seen from Zion Canyon Visitor Center	streams and ponds	siltstone and sandstone
Chinle Formation	purpleish slopes	above Rockville	streams	shale, loose clay and conglomerate
Moenkopi Formation	chocolate cliffs with white bands	rocky slopes from Virgin to Rockville	shallow sea	shale, siltstone, sandstone, mudstone, and limestone
Kaibab Formation	cliffs	escarpment of Hurricane Fault along I-15 near Kolob Canyons	shallow sea	limestone

Cowardin System
If the system is a wetland, check off the name of the USFWS system which best describes its hydrology and landform. Indicate "upland" if the system is not a wetland.

Assess the hydrologic regime of the plot using the descriptions below (adapted from Cowardin et al. 1979).
SEMIPERMANENTLY FLOODED - Surface water persists throughout growing season in most years except during periods of drought. Land surface is normally saturated when water level drops below soil surface. Includes Cowardin's Intermittently Exposed and Semipermanently Flooded modifiers.

SEASONALLY FLOODED - Surface water is present for extended periods during the growing season, but is absent by the end of the growing season in most years. The water table after flooding ceases is very variable, extending from saturated to a water table well below the ground surface. Includes Cowardin's Seasonal, Seasonal-Saturated, and Seasonal-Well Drained modifiers.

SATURATED - Surface water is seldom present, but substrate is saturated to surface for extended periods during the growing season. Equivalent to Cowardin's Saturated modifier.

TEMPORARILY FLOODED - Surface water present for brief periods during growing season, but water table usually lies well below soil surface. Often characterizes flood-plain wetlands. Equivalent to Cowardin's Temporary modifier.

INTERMITTENTLY FLOODED - Substrate is usually exposed, but surface water can be present for variable periods without detectable seasonal periodicity. Inundation is not predictable to a given season and is dependent upon highly localized rain storms. This modifier was developed for use in the arid West for water regimes of Playa lakes, intermittent streams, and dry washes but can be used in other parts of the U.S. where appropriate. This modifier can be applied to both wetland and non-wetland situations. Equivalent to Cowardin's Intermittently Flooded modifier.

PERMANENTLY FLOODED - Water covers the land surface at all times of the year in all years. Equivalent to Cowardin's "permanently flooded."

UNKNOWN - The water regime of the area is not known. The unit is simply described as a non-tidal wetland.

Environmental Comments
Enter any additional noteworthy comments on the environmental setting. This field can be used to describe site history such as fire events (date since last fire or evidence of severity) as well as other disturbance or reproduction factors.

Soil Taxon/Description ***This does not apply for the Zion Project***

Ground Cover
Estimate the approximate percentage of the total surface area covered by each category. Only include categories with over 5 percent cover.

Soil Texture
Using the key below, assess average soil texture.

Simplified Key to Soil Texture (Brewer and McCann 1982)

A1 Soil does not remain in a ball when squeezed..sand

A2 Soil remains in a ball when squeezed...B

B1 Squeeze the ball between your thumb and forefinger, attempting to make a ribbon that you push up over your finger.
Soil makes no ribbon..……………………………loamy sand

B2 Soil makes a ribbon; may be very short...C

C1 Ribbon extends less than 1 inch before breaking...D

C2 Ribbon extends 1 inch or more before breaking...E

D1 Add excess water to small amount of soil
Soil feels at least slightly gritty………………………………….……….loam or sandy loam

D2 Soil feels smooth...…...................................silt loam

E1 Soil makes a ribbon that breaks when 1 2 inches long;
cracks if bent into a ring...F

E2 Soil makes a ribbon 2+ inches long; does not crack when bent into a ring……………..…G

F1 Add excess water to small amount of soil;
soil feels at least slightly gritty.......……………......….............sandy clay loam or clay loam

F2 Soil feels smooth...…..............................silty clay loam or silt

G1 Add excess water to a small amount of soil;
soil feels at least slightly gritty................……………………………….………sandy clay or clay

G2 Soil feels smooth..…...................................silty clay

Soil Drainage
The soil drainage classes are defined in terms of (1) actual moisture content (in excess of field moisture capacity) and (2) the extent of the period during which excess water is present in the plant-root zone. It is recognized that permeability, level of groundwater, and seepage are factors affecting moisture status. However, because these are not easily observed or measured in the field, they cannot generally be used as criteria of moisture status. It is further recognized that soil profile morphology, for example mottling, normally, but not always, reflects soil moisture status. Although soil morphology may be a valuable field indication of moisture status, it should not be the overriding criterion. Soil drainage classes cannot be based solely on the presence or absence of mottling. Topographic position and vegetation as well as soil morphology are useful field criteria for assessing soil moisture status.

RAPIDLY DRAINED - The soil moisture content seldom exceeds field capacity in any horizon except immediately after water addition. Soils are free from any evidence of gleying throughout the profile. Rapidly drained soils are commonly coarse textured or soils on steep slopes.

WELL DRAINED - The soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year. Soils are usually free from mottling in the upper 3 feet, but may be mottled below this depth. B horizons, if present, are reddish, brownish, or yellowish.

MODERATELY WELL DRAINED - The soil moisture in excess of field capacity remains for a small but significant period of the year. Soils are commonly mottled (chroma < 2) in the lower B and C horizons or below a depth of 2 feet. The Ae horizon, if present, may be faintly mottled in fine-textured soils and in medium-textured soils that have a slowly permeable layer below the solum. In grassland soils the B and C horizons may be only faintly mottled and the A horizon may be relatively thick and dark.

SOMEWHAT POORLY DRAINED - The soil moisture in excess of field capacity remains in subsurface horizons for moderately long periods during the year. Soils are commonly mottled in the B and C horizons; the Ae horizon, if present, may be mottled. The matrix generally has a lower chroma than in the well-drained soil on similar parent material.

POORLY DRAINED - The soil moisture in excess of field capacity remains in all horizons for a large part of the year. The soils are usually very strongly gleyed. Except in high-chroma parent materials the B, if present, and upper C horizons usually have matrix colors of low chroma. Faint mottling may occur throughout.

VERY POORLY DRAINED - Free water remains at or within 12 inches of the surface most of the year. The soils are usually very strongly gleyed. Subsurface horizons usually are of low chroma and yellowish to bluish hues. Mottling may be present but at the depth in the profile. Very poorly drained soils usually have a mucky or peaty surface horizon.

VEGETATION DESCRIPTION

Leaf Phenology

Select the value which best describes the leaf phenology of the dominant stratum. The dominant stratum is the uppermost stratum that contains at least 10% cover.

EVERGREEN - Greater than 75% of the total woody cover is never without green foliage.

COLD DECIDUOUS - Greater than 75% of the total woody cover sheds its foliage in connection with an unfavorable season mainly characterized by winter frost.

MIXED EVERGREEN - COLD DECIDUOUS - Evergreen and deciduous species generally contribute 25-75% of the total woody cover. Evergreen and cold-deciduous species admixed.

PERENNIAL - Herbaceous vegetation composed of more than 50% perennial species.

ANNUAL - Herbaceous vegetation composed of more than 50% annual species.

Leaf Type
Select one value which best describes the leaf form of the dominant stratum. The dominant stratum is the uppermost stratum that contains at least 10% cover.

BROAD-LEAVED - Woody vegetation primarily broad-leaved (generally contributes greater than 50 percent of the total woody cover).

NEEDLE-LEAVED - Woody vegetation primarily needle-leaved (generally contributes greater than 50 percent cover).

MICROPHYLLOUS - Woody cover primarily microphyllous.

GRAMINOID - Herbaceous vegetation composed of more than 50 percent graminoid/stipe leaf species.

FORB (BROAD-LEAF-HERBACEOUS) - Herbaceous vegetation composed of more than 50% broad-leaf forb species.

PTERIDOPHYTE - Herbaceous vegetation composed of more than 50 percent species with frond or frond-like leaves.

Physiognomic Class
Choose one:

Forest: Trees with their crowns overlapping (generally forming 60-100% cover).

Woodland: Open stands of trees with crowns not usually touching (generally forming 25-60% cover). Canopy tree cover may be less than 25% in cases where it exceeds shrub, dwarf-shrub, herb, and nonvascular cover, respectively.

Shrubland: Shrubs generally greater than 0.5 m tall with individuals or clumps overlapping to not touching (generally forming more than 25% cover, trees generally less than 25% cover). Shrub cover may be less than 25% where it exceeds tree, dwarf-shrub, herb, and nonvascular cover, respectively. Vegetation dominated by woody vines is generally treated in this class.

Dwarf-Shrubland: Low-growing shrubs usually under 0.5 m tall. Individuals or clumps overlapping to not touching (generally forming more than 25% cover, trees and tall shrubs generally less than 25% cover). Dwarf-shrub cover may be less than 25% where it exceeds tree, shrub, herb, and nonvascular cover, respectively

Herbaceous: Herbs (graminoids, forbs, and ferns) dominant (generally forming at least 25% cover; trees, shrubs, and dwarf-shrubs generally with less than 25% cover). Herb cover may be less than 25% where it exceeds tree, shrub, dwarf-shrub, and nonvascular cover, respectively.

Nonvascular: Nonvascular cover (bryophytes, non-crustose lichens, and algae) dominant (generally forming at least 25% cover). Nonvascular cover may be less than 25% where it exceeds tree, shrub, dwarf-shrub, and herb cover, respectively.

Sparse Vegetation: Abiotic substrate features dominant. Vegetation is scattered to nearly absent and generally restricted to areas of concentrated resources (total vegetation cover is typically less than 25% and greater than 0%).

Strata/Lifeform, Height, Cover, Diagnostic Species
Visually divide the community into vegetation layers (strata). Indicate the average height class of the stratum in the first column, using the Height Scale on the form. Enter the average percent cover class of the whole stratum in the second column, using the Cover Scale on the form. Height and Cover classes are also listed below.

Trees are defined as single- or few-stemmed woody plants, generally greater than 5 m in height and 10 cm DBH at maturity and under optimal growing conditions. Individuals can be determined relatively easily. Shrubs are defined as multiple-stemmed woody plants generally less than 5 m in height at maturity and under optimal growing conditions, and determining individuals can sometimes be difficult. At Zion, Quercus gambelii can occur in either shrub or tree form.

Herbaceous layers are Ht = total, H1 = Graminoids (grass, sedge, rush), H2 = Forbs (Dicot herbaceous), H3 = Ferns and Fern allies, and H4 tree seedlings. List the dominant species in each stratum. If species known to be diagnostic of a particular vegetation type are present, list these as well, marking them with an asterisk.

Cover Scale for Strata		Height Scale for Strata	
T	<1%	01	<0.5 m
P	1-5%	02	0.5-1m
1	5-15%	03	1-2 m
2	15-25%	04	2-5 m
3	25-35%	05	5-10 m
4	35-45%	06	10-15 m
5	45-55%	07	15-20 m
6	55-65%	08	20-35 m
7	65-75%	09	35-50 m
8	75-85%	10	>50 m
9	85-95%		
10	95-100%		

Animal Use Evidence
Comment on any evidence of use of the plot/polygon by non-domestic animals (i.e., tracks, scat, gopher or prairie dog mounds, etc.). Notes on domestic animals should be made in the field below.

Natural and Anthropogenic Disturbance
Comment on any evidence of natural or anthropogenic disturbance and specify the source.

Other Comments
Any other comments.

Species/DBH/Percent Cover Table
Starting with the uppermost stratum, list all the species present and cover class (using the 12 point scale) and percent cover of each species in that particular stratum. Indicate strata in the left-hand columns. If in the tree layer (single-stemmed woody plants, generally 5 m in height or greater at maturity), note in the "T" column if T1 (emergent tree), T2 (tree canopy), or T3 (tree sub-canopy). If in the shrub layer, note in the "S" column if S1 (tall shrub, > 2m), S2 (short shrub, < 2m), or S3 (dwarf shrub. < 0.5m). If in the ground layer, note in the "G" column if H1 (herbaceous - graminoid), H2 (Herbaceous Forb), H3 (Herbaceous Fern), H4 (Tree Seedlings), N (nonvascular other than ferns), V (vine/liana), or E (epiphyte).

*For plots with trees, estimate cover of seedlings, saplings, mature (all others), and total cover for **each** tree species. Use a separate line for each and assign the most appropriate strata class (by height). Seedlings are generally less than 1.5 m, but that may vary by species.

Also record the DBH (in cm) of all trees above 10 cm diameter. For multi-stemmed individuals, separate the measurements with a comma. Also tally tree stems with DBH between 5-10 cm (See Tree DBH Form). For plots with very high tree density DBH measurements will be done in a subplot. If the number of trees with a DBH greater than 10 cm is more than about 25, divide the plot into quarters and measure the DBH of trees in the southeast quadrant, or the quadrant nearest southeast. CLEARLY NOTE on the form that this is what you've done.

CONSIDERATIONS FOR MISSION PLANNING:
PHASE II FIELD SAMPLING FOR ZION VEGETATION MAPPING PROJECT Draft 2000

Planning for the day: (ecologist/team leader)
- Safety and sustenance issues (plenty of food, water, first-aid kit bring water filter if long steep hike where water can be obtained)
- Field communications: Develop plan with other team(s)(if necessary) for radio check-in time re: plot types and contingencies for duplication problems
- Do you have radio and are batteries charged?
- check on GPS (batteries, memory available, waypoints for priority samples logged using spreadsheet?)
- check list for all other field equipment
- clipboard
- pens, pencils
- compass-clinometer
- two tape measures
- plastic bags for plants
- masking tape and sharpies for labeling specimens
- If longer mission, small plant press with adequate blotters and newspaper
- Bring sufficient field forms for all possible samples
- Bring all ancillary information. (cheat sheet, species list, key, sampling priority list for zone, fuels protocol, main sampling protocol)
- Plan day's mission before departure for day using one copy per team of a) USGS quad, b) hardcopy DOQQ with flagged points, and c) aerial photo with coded overlay
- considerations for mission planning:
- considerations based on topography, existing access routes, density and complexity of vegetation (more time for forest and woodland plots, less for herbaceous and scrub),
- considerations based on priority needs, and
- considerations based on possible redundancy of other team (adequate alternative samples)

Planning for the Week:
With which 7.5' quads will you be working?
Do you have all appropriate maps, photos and DOQQ's?
Develop an estimate of reasonable expectations of plots to choose from for each team broken up by day and based on an estimate of individual team's travel logistics for the week.
Develop plan of attack for the week to capture all essential associations in work area.
Balance points two and three above with the expected work schedule of the teams and ensure adequate time-off and reduce over-time concerns.
Do you have all necessary information for weekly planning? a) DOQQ's for the zone, b) adequate field copies of air photos (1 per team if both will be working same photo) , c) blank field forms.

Communication with management team (Jim, Marion, Keith, Dan Cohan, or some appropriate subset) and field crews.

- update matrix of sampled plots by type, (enter plot number and provisional community name in plots database.
- all uncertainties dealt with (new types seen should we sample?, problems with interpreting PI information, personnel issues, problems in interpreting classification/key, park-related logistics.).
- Organization of field crews:
- gather Quality control (Q.C.'ed) field forms (allow time for your Q.C. and resolving your questions about the forms)
- obtain all plants not identified (allow time for plant I.D.)
- what were your questions about the polygons visited during the week?
- What was accomplished, what was not accomplished?
- Pass on the developments and questions to the management team on a regular basis. Don't let them build up too long.

Materials checklist
road / trail maps
DBH tape
2 tape measure(s)
DBH tape or plastic DBH measurement device
compass
plot markers – large nails or cut rebar (1 per plot, plus extra)
small sledgehammer (for driving plot markers into ground)
PLGR
GPS receiver (checked daily to ensure that it is set to NAD 83)
radio
clinometer
camera & film (allow at least 3 exposures per plot)
baggies – for unidentified plant samples
plant press & paper
pens / permanent markers
Plot Survey forms
Forest Fuel forms
Accuracy Assessment Point forms
white board
dry-erase markers (for white board)
most recent version of provisional classification of the Park x number of plots needed per type (updated approx. every 2 weeks)

ZION CODE LIST – Draft cheatsheet

LANDFORM
Arroyo
Alluvial fan
Alluvial flat
Alluvial terrace
Badland
Bajada
Basin
Bench
Bottomland
Butte
Canyon
Channel
Cinder cone
Cliff
Colluvial slope
Cuesta
Drainage channel (undifferentiated)
Dune
Earth flow
Eroded bench
Eroding stream channel system
Erosional stream terrace
Escarpment
Flood plain
Fluvial
Gorge
Hill
Hillslope bedrock outcrop
Hogback
Knob
Knoll
Lake/pond
Lake bed
Lake plain
Lake terrace
Lava flow (undifferentiated)
Ledge
Mesa
Mound
Mountain
Mud flat
Pinnacle
Plateau
Playa
Ravine
Ridge
Ridge & valley
Ridgetop bedrock outcrop
Rock fall avalanche
Rim
Riverbed
Saddle
Scour
Seep
Upper 1/3 of slope
Middle 1/3 of slope
Lower 1/3 of slope
Soil creep slope
Stream terrace (undifferentiated)
Streambed
Swale
Talus
Toe slope
Valley floor
Wash

TOPOGRAPHIC POSITION

Designation	Synonym(s)
Interfluve	crest, summit, ridge
High slope	shoulder slope, upper slope, convex creep slope
High level	mesa
Midslope	transportational midslope, middle slope
Backslope	dipslope
Step in slope	ledge, terracette
Lowslope	lower slope, foot slope, colluvial footslope
Toeslope	alluvial toeslope
Low level	terrace
Channel wall	bank
Channel bed	narrow valley bottom, gully, arroyo/wash
Basin floor	depression

SURFICIAL GEOLOGY
Alluvium
Alluvium Remnants
Carmel Formation
Chinle Formation
Dakota Formation
Kaibab Formation
Kayenta Formation
Lake and Pond Deposits
Lake Deposits
Moenave Formation
Moenkopi Formation
Navajo Sandstone
Slide Deposits
Slide Deposits – Calcite
Temple Cap Formation
Volcanic Rocks
Volcanic Rocks – Tephra

ASPECT
Flat (n/a)
Variable

N	338-22
NE	23-67
E	68-112
SE	113-157
S	158-202
SW	203-247
W	248-292
NW	293-337

SOIL TEXTURE
Sand
Loamy sand
Sandy loam
Loam
Silt loam
Clay loam
Silt
Clay
Sandy Clay
Silty Clay
Peat
Muck

DRAINAGE
Rapidly drained
Well drained
Moderately well drained
Somewhat poorly drained
Poorly drained
Very poorly drained

IMPACTS
Recent Fire Suppression Activity (e.g. fire lines)
Mountain Pine Beetle Damage
Blister Rust (specify tree species and mortality)
Mistletoe (specify tree species)
Trespass Grazing Evidence
Development
Recreation (campsites, etc.)
Significant Weed Invasion

ACCURACY ASSESSMENT POINT FORM

IDENTIFIERS/LOCATORS

Field Point Code ____ Database Point Code _______________________

State __ Park Name ____________________________________ Park Site Name __________________________

Quad Name____ QuadCode____________________________

Primary Name Veg Assoc: ____

Secondary Name Veg Assoc:____

Other Veg Assoc within 50 m ____

Classification Comments:

GPS file name________________ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N

GPS Error ________________ m

please do not complete the following information when in the field

Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone_____

Survey Date_____________
Surveyors____

ENVIRONMENTAL DESCRIPTION

Elevation ______________________ Slope _____________________Aspect_________________________

Topographic Position

Landform

Environmental Comments (including hydrology):

Unvegetated Surface: *(please use the cover scale below)*
___ Bedrock
___ Litter, duff
___ Wood (> 1 cm)
___ Large rocks (cobbles, boulders > 10 cm)
___ Small rocks (gravel, 0.2-10 cm)
___ Sand (0.1-2 mm)
___ Bare soil
___ Other:_________________________

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	HEIGHT (M) SCALE	COVER
Trees and Shrubs	___Broad-leaved	___Forest	01 -<0.5	T - <1%
___Evergreen	___Needle-leaved	___Woodland	02 - 0.5-1	01 - 1-5%
___Cold-deciduous	___Mixed broad-lvd/Needle-lvd	___Shrubland	03 - 1-2	02 - 6-15%
___Drought-deciduous	___Microphyllous	___Dwarf-shrubland	04 - 2-5	03 - 16-25%
___Mixed evergreen - cold-deciduous	___Graminoid	___Herbaceous	05 - 5-10	04 - 26-35%
___Mixed everg. - drought-deciduous	___Forb	___Nonvascular	06 - 10-15	05 - 36-45%
Herbs	___Pteridophyte	___Sparsely Vegetated	07 - 15-20	06 - 46-55%
___Annual			08 - 20-35	07 - 56-65%
___Perennial			09 - 35-50	08 - 65-75%
			10 ->50	09 - 76-85%
				10 - 86-95%
				11- 96-100%

Strata	Height Class	Cover Class	Dominant species (mark any known diagnostic species with a *)	Cover Class
T1 Emergent	_____	_____		
T2 Canopy	_____	_____		
T3 Sub-canopy	_____	_____		
S1 Tall shrub	_____	_____		
S2 Short Shrub	_____	_____		
S3 Dwarf-shrub	_____	_____		
H Herbaceous	_____	_____		
N Non-vascular	_____	_____		
V Vine/liana	_____	_____		
E Epiphyte	_____	_____		

APPENDIX G: ZION Helicopter Documents

MEMORANDUM

To: Zion Vegetation Mapping Team
From: Dan Cogan
Date: August 30, 2000
Subject: Summary of Helicopter Sampling Effort

On August 21, 2000, The Nature Conservancy (TNC) conducted vegetation sampling in remote locations throughout Zion National Park as part of the USGS/NPS Vegetation Mapping Program. This operation was supported by the United States Bureau of Reclamation (BOR) and the BOR's helicopter based in Salt Lake City, UT. The helicopter was piloted by Steve Chubbuck from the BOR's Upper Colorado Region.

Planning for the project was initiated by identifying potential sampling target sites. This selection was made by Dan Cohen and Dan Cogan based on locations of isolated mesa tops, sheer tower summits, canyon bottoms, and other areas inaccessible by foot. This selection resulted in 77 potential targets (see attachment) that were prioritized by their size, vegetation diversity, and grouped into four flight zones based on recommendations from Zion's Wilderness Committee and Aviation Manager. The four zones split the targets into four missions with zone boundaries based on minimizing overflights of sensitive Park areas, such as the main canyon.

The implementation of the study occurred over each of the four zones with each zone taking one day to complete. Each flight zone had a designated helispot located to maximize helicopter logistics and reduce helicopter flight path redundancy. During each day, an overflight reconnaissance was conducted either as a separate mission or in conjunction with shuttling a field team. Reconnaissance provided an opportunity to evaluate the targets for flat, clear helicopter landing sites and gave some opportunity to acquire photo verification. After the reconnaissance flight, the helicopter was solely responsible for shuttling field teams to and from landable targets.

On Monday, August 21, work started in Flight Zone 1, comprising the Kolob District of the Park (northern-most portion). At 8:00 a.m. all of the vegetation field crews met with Julie Thompson (TNC) at the Kolob Visitor Center and were briefed on the project. At 9:15 all project participants met at the helispot located at the terminus of the Kolob Scenic drive. Here, everyone was given a rigorous and thorough review of helicopter safety by Steve Chubbuck. Upon completion, four 2-person field teams were identified containing a botanist and a sampling (plot form) expert and shuttled to target sites. In addition, a radio service team was shuttled to Timber Top Mesa to perform maintenance and repairs to a NPS radio repeater.

On Tuesday, August 22, the project was moved to Fight Zone 2. This area was below the KT road, above the Coalpits watershed and west of the North Fork of the Virgin River. The helispot location was adjacent to a place called the Ponderosa Pine Pullout on the left side of the KT Road about 1/8 mile above the parking area for the wildcat trail head. Five two-person field teams were used to sample target sites in this area.

On Wednesday, August 23, work shifted to Flight Zone 3, basically the entire Coalpits drainage area west of the North Fork of the Virgin River. No reconnaissance flight was used and the field teams were immediately shuttled to their first target site. Again, five two-person teams were used to conduct the sampling. A radio service team was also shuttled to West Temple Mesa to perform maintenance and repairs to another NPS radio repeater.

Work was wrapped up in Flight Zone 4 on Thursday, August 24. This zone included the entire Park east of the North Fork of the Virgin River. One field team and Dan Cohan were shuttled to the Dakota Hill area (north east corner of the Park) to sample the vegetation and survey for potential goshawk nesting areas. The helispot location for this zone was at the Clear Creek Ranch east of the Park's east entrance. Six two-person field teams were used in this area.

All participates in this endeavor were conducted on and off the aircraft by NPS helicopter crewmembers and were required to wear leather boots, fire resistant flight suites and helmets while in the helicopter. Leather boots also helped reduce the risk of transporting noxious weed seeds into pristine areas. Denise Louie (Zion botanist) further addressed this issue of non-native contamination in her following checklist:

Ways to prevent carrying exotic plant seed into isolated mesa tops:

1) Each morning - visually check shoelaces, socks, pant cuffs, hats, everything - to make sure no seeds have hitchhiked onto you.

2) Everyone will wear gaitors at all times during helicopter fieldwork. This will reduce ability for seed to catch on shoelaces, socks, pant cuffs.

3) Prior to boarding the aircraft (both at the helispot and from the mesa top) - visually inspect all possible clothing surfaces where seed could have hitched onto you.

4) We will bring spray bottles filled w/ water so you can wash off the bottom of shoes if needed.

5) Be extra aware of this issue - it would be really awful to be responsible for introducing an invasive non-native plant into a pristine area!

Thanks for your help!

Upon landing at each target site a GPS fix was recorded creating a point coverage of helicopter landing sites for the Park administration. GPS locations and ground photos were also recorded for each vegetation plot as specified in the protocols. All GPS data collected were set to UTM projection and coordinates in NAD27.

In summary, this project was completed in four working days representing **24.1** flight hours. A total of **78** vegetation plots were sampled at **31** remote areas. The information contained in these plots represents unique baseline data for relatively inaccessible and pristine areas of Zion. The plots collected on this project will be combined with similar plots collected in 1999 and 2000 for ordination analysis by TNC ecologists.

Undoubtedly, the valuable data collected during this trip will greatly enhance our understanding of the distribution and composition of Zion's plant communities both for this project and many others. Fortunately this project occurred without incident allowing everyone to go home safe and sound. This commitment to safety reflects the professionalism of those involved, even while under the stress of a complex and challenging endeavor. The following people should be commended for their participation; they include:

Zion National Park

Research and Resource Management

Jeff Bradybaugh
Dan Cohan
Denise Louie
Clare Poulson
Sunshine Ciccone

Fire Program

Art Latteral
Henry Bastian
Mike Lewelling
Kirsten Gillman
Mark Oetzmann
Kelly Mathis
Dana Cohen

The Bureau of Reclamation

Jim Von Loh
Dan Cogan
Mike Pucherelli

The Nature Conservancy

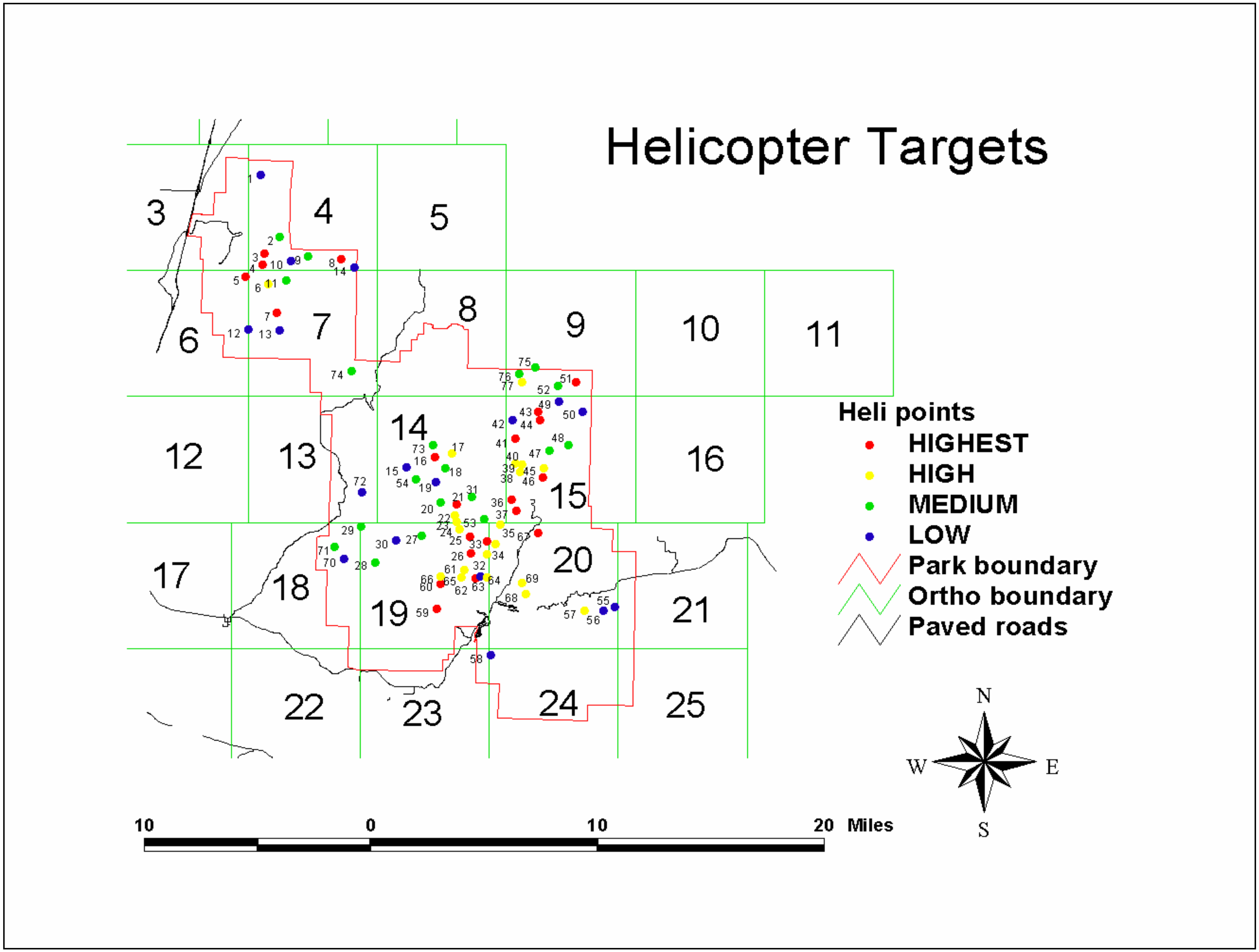
Keith Schulz
Julie Thompson
Kelly Lewelling
Frank "Buddy" Smith

Brigham Young University

Dr. Duane Atwood
Dr. Stanley Welsh (emeritus)

Miscellaneous

Margret Malm
Dr. William Reid
Marti Atkins


Helicopter Targets
Heli points
HIGHEST
HIGH
MEDIUM
LOW
Park boundary
Ortho boundary
Paved roads
10
0
10
20 Miles
N
W
E
S

APPENDIX H: ZION Species List

(List compiled from the 1999 and 2000 sample plots, not a complete list of species)
(Genus only records indicate an unknown species)

Family	Scientific Name	Common Name
Aceraceae	*Acer grandidentatum* Nutt.	bigtooth maple
	Acer negundo L.	boxelder
Agavaceae	*Yucca baccata* Torr.	banana yucca
	Yucca elata var. utahensis (McKelvey) Reveal	Utah yucca
Anacardiaceae	*Rhus aromatica* Ait.	fragrant sumac
	Rhus trilobata Nutt.	skunkbush sumac
	Rhus trilobata var. trilobata Nutt.	skunkbush sumac
Apiaceae	*Osmorhiza depauperata* Phil.	bluntseed sweetroot
	Osmorhiza occidentalis (Nutt. ex Torr. & Gray) Torr.	western sweetroot
Asclepiadaceae	*Asclepias subverticillata* (Gray) Vail	whorled milkweed
Aspleniaceae	*Asplenium* L.	spleenwort
Asteraceae	*Achillea millefolium* L.	common yarrow
	Agoseris Raf.	agoseris
	Ambrosia acanthicarpa Hook.	flatspine burr ragweed
	Antennaria Gaertn.	pussytoes
	Antennaria dimorpha (Nutt.) Torr. & Gray	low pussytoes
	Arnica L.	arnica
	Artemisia campestris L.	field sagewort
	Artemisia dracunculus L.	wormwood
	Artemisia filifolia Torr.	sand sagebrush
	Artemisia ludoviciana Nutt.	Louisiana sagewort
	Artemisia nova A. Nels.	black sagebrush
	Artemisia tridentata Nutt.	big sagebrush
	Artemisia tridentata ssp. tridentata Nutt.	basin big sagebrush
	Artemisia tridentata ssp. vaseyana (Rydb.) Beetle	mountain big sagebrush
	Aster L.	aster
	Aster glaucodes Blake	gray aster
	Baccharis emoryi Gray	Emory's baccharis
	Baccharis L.	baccharis
	Baccharis salicifolia (Ruiz & Pavon) Pers.	mule's fat
	Baileya multiradiata Harvey & Gray ex Gray	desert marigold
	Balsamorhiza sagittata (Pursh) Nutt.	arrowleaf balsamroot
	Brickellia Ell.	brickellia
	Brickellia atractyloides Gray	spearleaf brickellbush
	Brickellia californica (Torr. & Gray) Gray	California brickellbush
	Brickellia grandiflora (Hook.) Nutt.	tasselflower brickellbush
	Brickellia longifolia S. Wats.	longleaf brickellbush
	Chaenactis DC.	chaenactis
	Chaenactis douglasii (Hook.) Hook. & Arn.	Douglas' dustymaiden
	Chaetopappa ericoides (Torr.) Nesom	rose heath
	Chrysothamnus Nutt.	rabbitbrush
	Chrysothamnus depressus Nutt.	longflower rabbitbrush
	Chrysothamnus viscidiflorus (Hook.) Nutt.	green rabbitbrush
	Cirsium P. Mill.	thistle
	Cirsium calcareum (M.E. Jones) Woot. & Standl.	Cainville thistle
	Cirsium vulgare (Savi) Ten.	bull thistle
	Cirsium wheeleri (Gray) Petrak	Wheeler's thistle
	Ericameria linearifolia (DC.) Urbatsch & Wussow	narrowleaf heathgoldenrod
	Ericameria nauseosa ssp. nauseosa var. nauseosa (Pallas ex Pursh) Nesom & Baird	rabbitbrush
	Ericameria parryi var. parryi (Gray) Nesom	rabbitbrush
	Erigeron L.	fleabane

Family	Scientific Name	Common Name
	Erigeron pumilus Nutt.	shaggy fleabane
	Erigeron speciosus var. macranthus (Nutt.) Cronq.	aspen fleabane
	Erigeron utahensis Gray	Utah fleabane
	Geraea canescens Torr. & Gray	hairy desertsunflower
	Grindelia squarrosa (Pursh) Dunal	curlycup gumweed
	Gutierrezia microcephala (DC.) Gray	threadleaf snakeweed
	Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed
	Helianthus petiolaris Nutt.	prairie sunflower
	Heliomeris multiflora var. multiflora Nutt.	showy goldeneye
	Hesperodoria scopularum (M.E. Jones) Greene	Grand Canyon glowweed
	Heterotheca villosa (Pursh) Shinners	hairy goldenaster
	Hymenopappus filifolius Hook.	fineleaf hymenopappus
	Lactuca serriola L.	prickly lettuce
	Machaeranthera canescens (Pursh) Gray	hoary aster
	Machaeranthera gracilis (Nutt.) Shinners	slender goldenweed
	Machaeranthera Nees	machaeranthera
	Petradoria pumila (Nutt.) Greene	grassy rockgoldenrod
	Pluchea sericea (Nutt.) Coville	arrowweed
	Senecio L.	groundsel
	Senecio eremophilus Richards.	desert groundsel
	Senecio integerrimus Nutt.	lambstongue groundsel
	Senecio multilobatus Torr. & Gray ex Gray	lobeleaf groundsel
	Senecio spartioides Torr. & Gray	broom groundsel
	Solidago L.	goldenrod
	Solidago velutina DC.	threenerve goldenrod
	Stephanomeria exigua Nutt.	small wirelettuce
	Stephanomeria Nutt.	wirelettuce
	Taraxacum officinale G.H. Weber ex Wiggers	common dandelion
	Tetradymia axillaris A. Nels.	longspine horsebrush
	Tetradymia canescens DC.	spineless horsebrush
	Tragopogon dubius Scop.	yellow salsify
Berberidaceae	*Mahonia repens* (Lindl.) G. Don	Oregongrape
Betulaceae	*Betula occidentalis* Hook.	water birch
Boraginaceae	*Cryptantha* Lehm. ex G. Don	cryptantha
	Cryptantha humilis (Gray) Payson	roundspike catseye
	Mertensia Roth	bluebells
	Mertensia arizonica Greene	aspen bluebells
Brassicaceae	*Arabis* L.	rockcress
	Arabis holboellii Hornem.	Holboell's rockcress
	Brassica L.	mustard
	Descurainia Webb & Berth.	tansymustard
	Descurainia pinnata (Walt.) Britt.	western tansymustard
	Draba L.	whitlowgrass
	Erysimum capitatum var. argillosum (Greene) R.J. Davis	sanddune wallflower
	Lesquerella S. Wats.	bladderpod
	Physaria chambersii Rollins	Chambers' twinpod
	Physaria newberryi Gray	Newberry's twinpod
	Rorippa nasturtium-aquaticum (L.) Hayek	watercress
	Stanleya pinnata (Pursh) Britt.	desert princesplume

Family	Scientific Name	Common Name
Cactaceae	*Echinocereus* Engelm.	hedgehog cactus
	Echinocereus engelmannii (Parry ex Engelm.) Lem.	saints cactus
	Echinocereus triglochidiatus Engelm.	kingcup cactus
	Opuntia P. Mill.	pricklypear
	Opuntia chlorotica Engelm. & Bigelow	dollarjoint pricklypear
	Opuntia echinocarpa Engelm. & Bigelow	staghorn cholla
	Opuntia erinacea Engelm. & Bigelow ex Engelm.	grizzlybear pricklypear
	Opuntia macrorhiza Engelm.	twistspine pricklypear
	Opuntia phaeacantha Engelm.	tulip pricklypear
	Opuntia whipplei Engelm. & Bigelow	Whipple cholla
Caprifoliaceae	*Sambucus* L.	elderberry
	Symphoricarpos oreophilus Gray	whortleleaf snowberry
Caryophyllaceae	*Arenaria* L.	sandwort
	Arenaria fendleri Gray	Fendler's sandwort
	Arenaria macradenia S. Wats.	Mojave sandwort
	Pseudostellaria jamesiana (Torr.) W.A. Weber & R.L. Hartman	tuber starwort
	Stellaria L.	starwort
Celastraceae	*Paxistima myrsinites* (Pursh) Raf.	boxleaf myrtle
Chenopodiaceae	*Atriplex canescens* (Pursh) Nutt.	fourwing saltbush
	Atriplex confertifolia (Torr. & Frem.) S. Wats.	shadscale saltbush
	Chenopodium fremontii S. Wats.	Fremont's goosefoot
	Salsola kali ssp. tragus (L.) Celak.	prickly Russian thistle
Commelinaceae	*Tradescantia occidentalis* (Britt.) Smyth	prairie spiderwort
Convolvulaceae	*Convolvulus arvensis* L.	field bindweed
	Ipomoea purpurea (L.) Roth	tall morningglory
Cupressaceae	*Cupressus arizonica* Greene	Arizona cypress
	Juniperus L.	juniper
	Juniperus osteosperma (Torr.) Little	Utah juniper
	Juniperus scopulorum Sarg.	Rocky Mountain juniper
Cyperaceae	*Carex* L.	sedge
	Carex geyeri Boott	elk sedge
	Carex microptera Mackenzie	smallwing sedge
	Carex nebrascensis Dewey	Nebraska sedge
	Carex occidentalis Bailey	western sedge
	Carex rossii Boott	Ross' sedge
	Carex utriculata Boott	Northwest Territory sedge
	Eleocharis R. Br.	spikerush
	Schoenoplectus americanus (Pers.) Volk. ex Schinz & R. Keller	chairmaker's bulrush
	Schoenoplectus tabernaemontani (K.C. Gmel.) Palla	softstem bulrush
	Scirpus L.	bulrush
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn	western brackenfern
Elaeagnaceae	*Elaeagnus angustifolia* L.	Russian olive
	Shepherdia rotundifolia Parry	roundleaf buffaloberry
Ephedraceae	*Ephedra nevadensis* S. Wats.	Nevada jointfir
	Ephedra viridis Coville	mormon tea

Family	Scientific Name	Common Name
Equisetaceae	*Equisetum* L.	horsetail
	Equisetum arvense L.	field horsetail
	Equisetum laevigatum A. Braun	smooth horsetail
	Equisetum variegatum Schleich. ex F. Weber & D.M.H. Mohr	variegated scouringrush
Ericaceae	*Arctostaphylos patula* Greene	greenleaf manzanita
	Arctostaphylos pungens Kunth	pointleaf manzanita
Euphorbiaceae	*Chamaesyce albomarginata* (Torr. & Gray) Small	whitemargin sandmat
	Chamaesyce fendleri (Torr. & Gray) Small	Fendler's sandmat
	Chamaesyce parryi (Engelm.) Rydb.	Parry's sandmat
	Euphorbia L.	spurge
	Tragia ramosa Torr.	branched noseburn
Fabaceae	*Astragalus* L.	milkvetch
	Astragalus subcinereus Gray	Silver's milkvetch
	Dalea searlsiae (Gray) Barneby	Searls' prairieclover
	Lathyrus L.	peavine
	Lotus L.	trefoil
	Lotus rigidus (Benth.) Greene	shrubby deervetch
	Lotus utahensis Ottley	Utah birdsfoot trefoil
	Lupinus L.	lupine
	Lupinus argenteus Pursh	silvery lupine
	Lupinus concinnus J.G. Agardh	scarlet lupine
	Lupinus sericeus Pursh	silky lupine
	Melilotus officinalis (L.) Lam.	yellow sweetclover
	Prosopis glandulosa Torr.	honey mesquite
	Psorothamnus fremontii (Torr. ex Gray) Barneby	Fremont's dalea
	Psorothamnus fremontii var. fremontii (Torr. ex Gray) Barneby	Fremont's dalea
	Trifolium L.	clover
	Trifolium gymnocarpon Nutt.	hollyleaf clover
	Trifolium longipes Nutt.	longstalk clover
	Vicia L.	vetch
	Vicia americana Muhl. ex Willd.	American vetch
Fagaceae	*Quercus gambelii* Nutt.	Gambel's oak
	Quercus turbinella Greene	shrub live oak
Gentianaceae	*Frasera speciosa* Dougl. ex Griseb.	showy frasera
Geraniaceae	*Geranium* L.	geranium
	Geranium caespitosum James	pineywoods geranium
Hydrophyllaceae	*Phacelia heterophylla* Pursh	varileaf phacelia
	Phacelia Juss.	phacelia
Iridaceae	*Sisyrinchium demissum* Greene	dwarf blueeyed grass
Juncaceae	*Juncus* L.	rush
	Juncus balticus Willd.	Baltic rush
	Juncus ensifolius Wikstr.	swordleaf rush
	Juncus longistylis Torr.	longstyle rush
	Juncus tenuis Willd.	poverty rush
	Juncus torreyi Coville	Torrey's rush
	Luzula parviflora (Ehrh.) Desv.	smallflowered woodrush
Lamiaceae	*Agastache urticifolia* (Benth.) Kuntze	nettleleaf giant hyssop
	Dracocephalum parviflorum Nutt.	American dragonhead
	Mentha arvensis L.	wild mint
	Monardella odoratissima Benth.	Pacific monardella

Family	Scientific Name	Common Name
	Salvia dorrii (Kellogg) Abrams	grayball sage
Liliaceae	*Allium* L.	wild onion
	Calochortus Pursh	Mariposa lily
	Calochortus nuttallii Torr. & Gray	sego lily
	Maianthemum racemosum ssp. Racemosum (L.) Link	feather Solomon's seal
	Maianthemum stellatum (L.) Link	starry false Solomon's seal
	Linum perenne L.	blue flax
Malvaceae	*Sphaeralcea* St.-Hil.	globemallow
	Sphaeralcea ambigua Gray	desert globemallow
	Sphaeralcea coccinea (Nutt.) Rydb.	scarlet globemallow
Monotropaceae	*Pterospora andromedea* Nutt.	woodland pinedrops
Nyctaginaceae	*Abronia fragrans* Nutt. ex Hook.	snowball sand verbena
	Allionia incarnata L.	trailing windmills
	Mirabilis multiflora (Torr.) Gray	Colorado four o'clock
Oleaceae	*Fraxinus anomala* Torr. ex S. Wats.	singleleaf ash
	Fraxinus velutina Torr.	velvet ash
Onagraceae	*Epilobium brachycarpum* K. Presl	autumn willowweed
	Epilobium canum ssp. garrettii (A. Nels.) Raven	Garrett's firechalice
	Gayophytum A. Juss.	groundsmoke
	Oenothera L.	eveningprimrose
	Oenothera cespitosa Nutt.	tufted eveningprimrose
	Oenothera longissima Rydb.	longstem eveningprimrose
	Oenothera pallida Lindl.	pale eveningprimrose
Pinaceae	*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.	white fir
	Pinus edulis Engelm.	twoneedle pinyon
	Pinus monophylla Torr. & Frem.	singleleaf pinyon
	Pinus ponderosa P.& C. Lawson	ponderosa pine
	Pseudotsuga menziesii (Mirbel) Franco	Douglas fir
Plantaginaceae	*Plantago patagonica* Jacq.	woolly plantain
Poaceae	*Achnatherum hymenoides* (Roemer & J.A. Schultes) Barkworth	Indian ricegrass
	Achnatherum lettermanii (Vasey) Barkworth	Letterman's needlegrass
	Achnatherum nelsonii ssp. nelsonii (Scribn.) Barkworth	Columbia needlegrass
	Agropyron cristatum (L.) Gaertn.	crested wheatgrass
	Agrostis exarata Trin.	spike bentgrass
	Agrostis stolonifera L.	creeping bentgrass
	Andropogon gerardii Vitman	big bluestem
	Aristida purpurascens Poir.	arrowfeather threeawn
	Aristida purpurea Nutt.	purple threeawn
	Bouteloua Lag.	grama
	Bouteloua barbata Lag.	sixweeks grama
	Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	blue grama
	Bromus L.	brome
	Bromus anomalus Rupr. ex Fourn.	nodding brome
	Bromus diandrus Roth	ripgut brome
	Bromus inermis Leyss.	smooth brome
	Bromus rubens L.	foxtail brome
	Bromus tectorum L.	cheatgrass
	Cenchrus longispinus (Hack.) Fern.	innocent-weed
	Dactylis glomerata L.	orchardgrass
	Elymus L.	wildrye

Family	Scientific Name	Common Name
	Elymus canadensis L.	Canada wildrye
	Elymus elymoides (Raf.) Swezey	bottlebrush squirreltail
	Elymus lanceolatus (Scribn. & J.G. Sm.) Gould	streambank wheatgrass
	Elytrigia intermedia (Host) Nevski	intermediate wheatgrass
	Elytrigia intermedia ssp. intermedia (Host) Nevski	intermediate wheatgrass
	Elytrigia repens (L.) Desv. ex B.D. Jackson	creeping quackgrass
	Festuca L.	fescue
	Frasera speciosa Dougl. ex Griseb.	showy frasera
	Hesperostipa comata ssp. comata (Trin. & Rupr.) Barkworth	needle and thread
	Hordeum brachyantherum Nevski	meadow barley
	Koeleria macrantha (Ledeb.) J.A. Schultes	prairie Junegrass
	Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi	alkali muhly
	Muhlenbergia montana (Nutt.) A.S. Hitchc.	mountain muhly
	Muhlenbergia porteri Scribn. ex Beal	bush muhly
	Muhlenbergia racemosa (Michx.) B.S.P.	marsh muhly
	Muhlenbergia thurberi Rydb.	Thurber's muhly
	Muhlenbergia wrightii Vasey ex Coult.	spike muhly
	Pascopyrum smithii (Rydb.) A. Love	western wheatgrass
	Phleum pratense L.	timothy
	Phragmites australis (Cav.) Trin. ex Steud.	common reed
	Pleuraphis jamesii Torr.	James' galleta
	Poa L.	bluegrass
	Poa fendleriana (Steud.) Vasey	muttongrass
	Poa pratensis L.	Kentucky bluegrass
	Poa secunda J. Presl	Sandberg bluegrass
	Polypogon Desf.	polypogon
	Pseudoroegneria spicata ssp. spicata (Pursh) A. Love	bluebunch wheatgrass
	Puccinellia distans (Jacq.) Parl.	weeping alkaligrass
	Schizachyrium scoparium (Michx.) Nash	little bluestem
	Sorghastrum nutans (L.) Nash	yellow Indiangrass
	Sporobolus R. Br.	dropseed
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed
	Stipa L.	needlegrass
	Triticum aestivum L.	common wheat
	Vulpia octoflora var. octoflora (Walt.) Rydb.	sixweeks fescue
Polemoniaceae	*Ipomopsis aggregata* (Pursh) V. Grant	skyrocket gilia
	Ipomopsis congesta ssp. Congesta (Hook.) V. Grant	ballhead gilia
	Leptodactylon pungens (Torr.) Torr. ex Nutt.	granite pricklygilia
	Phlox L.	phlox
	Phlox austromontana Coville	desert phlox
	Phlox hoodii Richards.	spiny phlox
	Phlox longifolia Nutt.	longleaf phlox
Polygonaceae	*Eriogonum* Michx.	eriogonum
	Eriogonum flavum Nutt.	yellow eriogonum
	Eriogonum inflatum Torr. & Frem.	Native American pipeweed
	Eriogonum microthecum Nutt.	slender buckwheat
	Eriogonum panguicense (M.E. Jones) Reveal	Panguitch buckwheat
	Eriogonum racemosum Nutt.	redroot buckwheat
	Eriogonum umbellatum Torr.	sulphur wildbuckwheat
	Polygonum L.	knotweed

Family	Scientific Name	Common Name
	Polygonum douglasii Greene	Douglas' knotweed
	Rumex acetosella L.	common sheep sorrel
Portulacaceae	*Claytonia perfoliata ssp. perfoliata var. nubigena* (Greene) Poelln.	miner's lettuce
Ranunculaceae	*Clematis columbiana* (Nutt.) Torr. & Gray	rock clematis
	Clematis ligusticifolia Nutt.	western white clematis
	Thalictrum fendleri Engelm. ex Gray	Fendler's meadowrue
Rhamnaceae	*Ceanothus fendleri* Gray	Fendler's ceanothus
Rosaceae	*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer	Saskatoon serviceberry
	Amelanchier utahensis Koehne	Utah serviceberry
	Cercocarpus intricatus S. Wats.	littleleaf mt. mahogany
	Cercocarpus ledifolius Nutt.	curlleaf mountain mahogany
	Cercocarpus montanus Raf.	true mountain mahogany
	Coleogyne ramosissima Torr.	blackbrush
	Holodiscus dumosus (Nutt. ex Hook.) Heller	rockspirea
	Ivesia sabulosa (M.E. Jones) Keck	Intermountain mousetail
	Peraphyllum ramosissimum Nutt.	squaw apple
	Petrophyton caespitosum (Nutt.) Rydb.	mat rockspirea
	Potentilla glandulosa Lindl.	gland cinquefoil
	Prunus L.	prunus
	Prunus virginiana L.	common chokecherry
	Purshia DC. ex Poir.	bitterbrush
	Purshia mexicana (D. Don) Henrickson	Mexican cliffrose
	Purshia stansburiana (Torr.) Henrickson	Stansbury cliffrose
	Purshia tridentata (Pursh) DC.	antelope bitterbrush
	Rosa woodsii Lindl.	Woods' rose
Rubiaceae	*Galium* L.	bedstraw
	Galium aparine L.	stickywilly
	Kelloggia galioides Torr.	milk kelloggia
Salicaceae	*Populus angustifolia* James	narrowleaf cottonwood
	Populus fremontii S. Wats.	Fremont's cottonwood
	Populus tremuloides Michx.	quaking aspen
	Salix L.	willow
	Salix exigua Nutt.	sandbar willow
	Salix gooddingii Ball	Goodding's willow
	Salix ligulifolia (Ball) Ball ex Schneid.	strapleaf willow
	Salix lucida Muhl.	shining willow
	Salix scouleriana Barratt ex Hook.	Scouler's willow
Santalaceae	*Comandra umbellata* (L.) Nutt.	bastard toadflax
	Comandra umbellata ssp. pallida (A. DC.) Piehl	pale bastard toadflax
Saxifragaceae	*Heuchera rubescens var. versicolor* (Greene) M.G. Stewart	pink alumroot
Scrophulariaceae	*Castilleja* Mutis ex L. f.	Indian paintbrush
	Castilleja applegatei ssp. martinii (Abrams) Chuang & Heckard	wavyleaf Indian paintbrush
	Castilleja linariifolia Benth.	Wyoming Indian paintbrush
	Collinsia parviflora Lindl.	smallflower blue eyed Mary
	Cordylanthus parviflorus (Ferris) Wiggins	purple bird's beak
	Linaria dalmatica (L.) P. Mill.	Dalmatian toadflax
	Penstemon Schmidel	penstemon
	Penstemon eatonii Gray	Eaton's penstemon

Family	Scientific Name	Common Name
	Penstemon lentus Pennell	handsome beardtongue
	Penstemon leonardii Rydb.	Leonard's beardtongue
	Penstemon linarioides Gray	toadflax penstemon
	Penstemon pachyphyllus Gray ex Rydb.	thickleaf beardtongue
	Penstemon palmeri Gray	Palmer's penstemon
	Penstemon rostriflorus Kellogg	Bridge penstemon
	Verbascum thapsus L.	common mullein
Solanaceae	*Datura* L.	datura
	Datura wrightii Regel	sacred thornapple
	Lycium pallidum Miers	pale wolfberry
	Nicotiana attenuata Torr. ex S. Wats.	coyote tobacco
	Physalis hederifolia Gray	ivyleaf groundcherry
	Physalis heterophylla Nees	clammy groundcherry
	Solanum elaeagnifolium Cav.	silverleaf nightshade
Tamaricaceae	*Tamarix ramosissima* Ledeb.	saltcedar
Typhaceae	*Typha angustifolia* L.	narrowleaf cattail
	Typha domingensis Pers.	southern cattail
Ulmaceae	*Celtis laevigata var. reticulata* (Torr.) L. Benson	netleaf hackberry
Verbenaceae	*Verbena bracteata* Lag. & Rodr.	bigbract verbena
Violaceae	*Viola* L.	violet
Viscaceae	*Phoradendron juniperinum* Engelm.	juniper mistletoe
Vitaceae	*Vitis arizonica* Engelm.	canyon grape
Zygophyllaceae	*Tribulus terrestris* L.	puncturevine

APPENDIX I: Photo Interpretation Mapping Conventions and Visual Key

Upland Grasslands

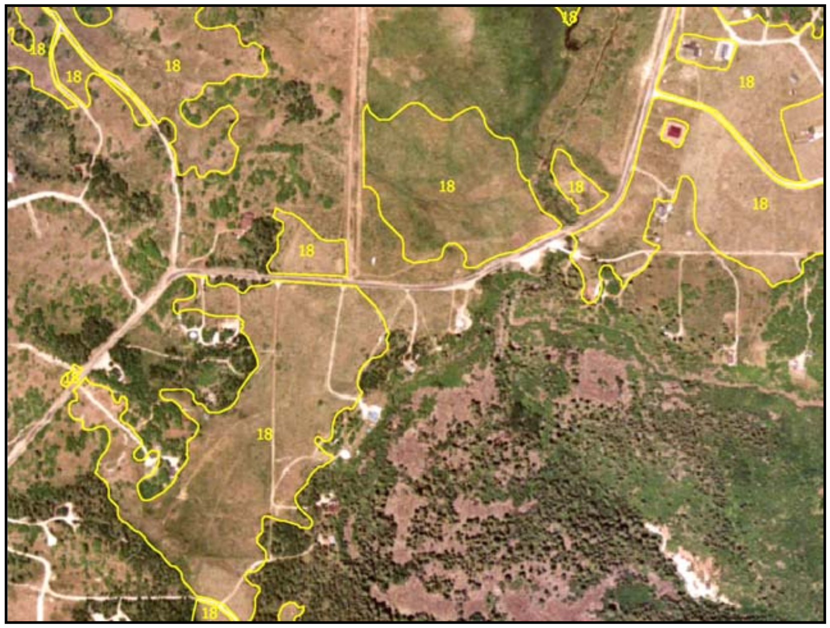
18 *Poa pratensis - Bromus inermis* Semi-natural Grassland Complex
Perennial Disturbed Grassland Complex

Associations:
-Bromus inermis - (Pascopyrum smithii) Semi-natural Herbaceous Vegetation
-Poa pratensis Semi-natural Seasonally Flooded Herbaceous Alliance

Common species:
Bromus inermis
Elymus lanceolatus
Poa pratensis
Achillea millefolium
Medicago lupulina
Trifolium longipes
Equisetum arvense

Project Specifics:
Frequency = 303 total polygons
86 polygons ZION, 217 polygons Environs
Area = 989 total acres
272 acres ZION, 717 acres Environs
Average Size = 3 acres

Photo Signature Example



Description:
This map class is common in old agricultural fields, pastures, road-sides, and other heavily disturbed areas. The presence of semi-natural grasses along with annual forbs yields a multitude of variation in the photo signature. This can vary from bright green in high moisture, high growth areas to dark brown and gray in arid and dormant sites. Typically this map class may be confused with other herbaceous types especially native grasslands

Ground Photos

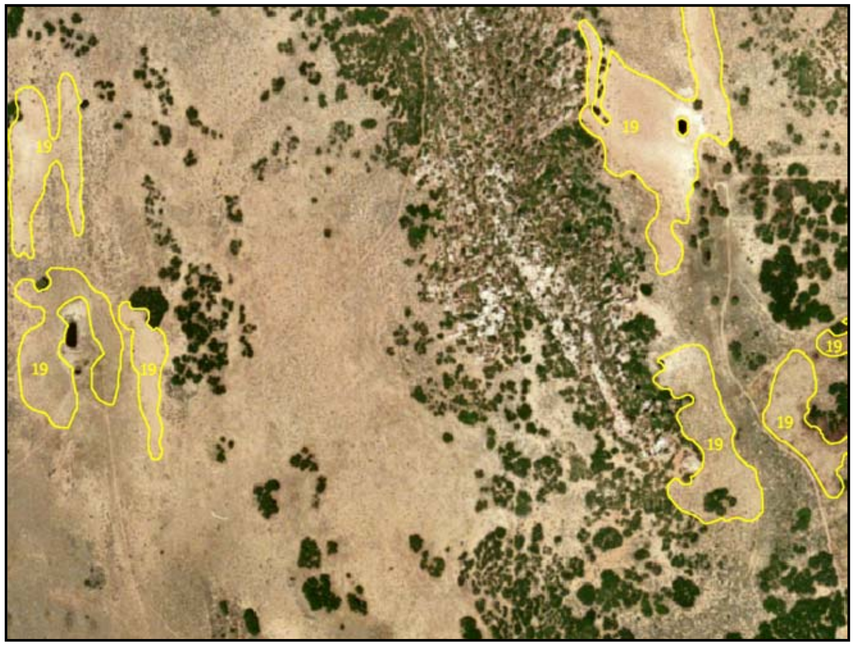
19 *Bromus tectorum* Semi-natural Herbaceous Alliance Cheatgrass Annual Disturbed Grassland

Alliance:
-Bromus tectorum Semi-natural Herbaceous Alliance

Common species:
Bromus tectorum

Project Specifics:
Frequency = 207 total polygons
70 polygons ZION, 137 polygons Environs
Area = 623 total acres
138 acres ZION, 485 acres Environs
Average Size = 3 acres

Photo Signature Example



Description:
This map class was based on field observations since no plots were taken. It was observed in disturbed areas of ZION at lower elevations and a variety of landforms, but was more common in lowlands, old agriculture fields and overgrazed pastures. This alliance is extensive in Main Canyon, Parunaweep Canyon, and Upper Coalpits. The photo signature for this type usually reflected the substrate since actively growing vegetation was minimal at the time of the photography.

Ground Photo

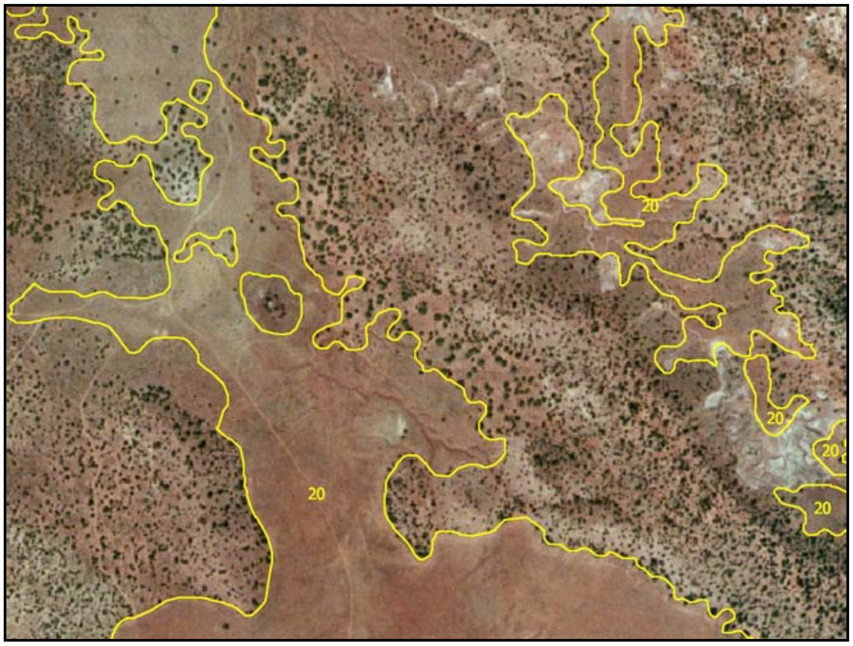
20 *Pleuraphis jamesii* Herbaceous Vegetation
James' Galleta Herbaceous Vegetation

Association:
-Pleuraphis jamesii Herbaceous Vegetation

Common species:
Pleuraphis jamesii
Opuntia spp.
G*utierrezia microcephala*
Bromus tectorum
Pinus monophylla
Juniperus osteosperma

Project Specifics:
Frequency = 55 total polygons
31 polygons ZION, 24 polygons Environs
Area = 1036 total acres
257 acres ZION, 778 acres Environs
Average Size = 19 acres

Photo Signature Example



Description:

This map class is common at ZION in the southern regions of the Park throughout the semi-arid and desert portions. Galleta grass is characterized on the area of the photos by a lack of shrubs and trees. In surrounding areas, Galleta grass is the primary understory species, which may cause some confusion when trees/shrubs become extremely sparse. The color of the photo signature can vary from red to brown to white depending on the dryness of the area and the color of the substrate.

Ground Photos

21 *Sporobolus cryptandrus* Great Basin Herbaceous Vegetation
Sand Dropseed Great Basin Herbaceous Vegetation

Association:
-*Sporobolus cryptandrus* Great Basin Herbaceous Vegetation

Common species:
Bromus tectorum
Pleuraphis jamesii
Sporobolus cryptandrus

Project Specifics:
Frequency = 111 total polygons
103 polygons ZION, 8 polygons Environs
Area = 177 total acres
144 acres ZION, 34 acres Environs
Average Size = 2 acres

Photo Signature Example

Description:
Sand Dropseed is common throughout the Park but mainly forms a true association on sand deposits alongside the Virgin River and its major tributaries. Other grass species are common in this type including a high percentage of non-native and semi-natural species. In disturbed areas alongside roads and trails this type also contains many early succession forbs and shrubs such as rabbitbrush and matchbrush snakeweed. This map class appears brown-tan due to the dryness of the sites and the color of sand substrate.

Ground Photo

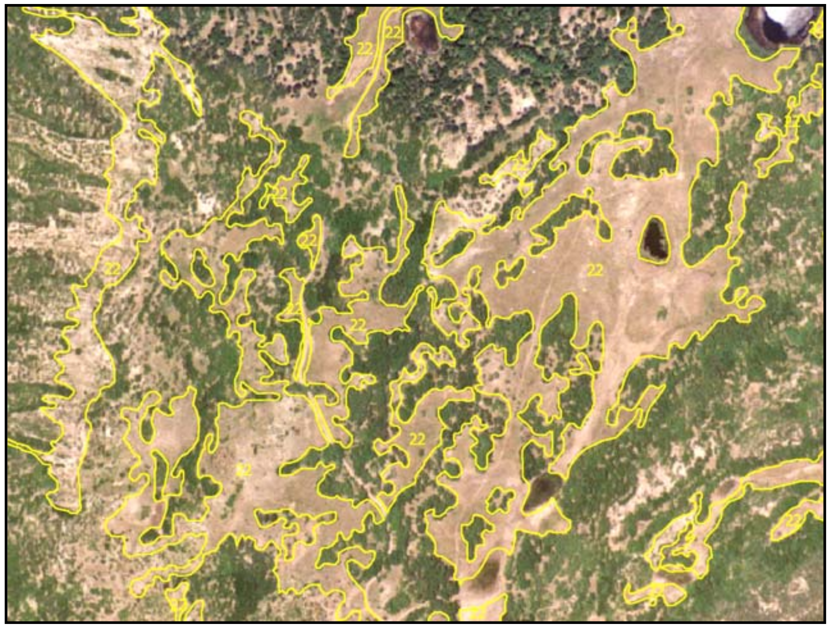
22 Dry Meadow Mixed Herbaceous Vegetation Mosaic

Associations:
-Bouteloua gracilis – Hesperostipa comata Herbaceous Vegetation
-Hesperostipa comata Great Basin Herbaceous Vegetation
-Muhlenbergia (pungens, montana)-Heterotheca villosa Herbaceous Vegetation
-Thinopyrum intermedium Herbaceous Vegetation Herbaceous Vegetation

Common species:
Bouteloua gracilis
Hesperostipa comata
Muhlenbergia pungens
Muhlenbergia Montana
Heterotheca villosa
Thinopyrum intermedium

Project Specifics:
Frequency = 987 total polygons
300 polygons ZION, 687 polygons Environs
Area = 2,233 total acres
554 acres ZION, 1679 acres Environs
Average Size = 2 acres

Photo Signature Example



Description:
This map class was fairly common from the mid to high elevations at ZION. This class represents grasslands occurring in either natural woodland meadows or previously cleared pastures. Typically no one or two species dominated these sites, instead small patches of different graminoids usually intermixed. In areas with high ground moisture this type was replaced by the Sedge-Rush Wet Meadow Herbaceous Vegetation Mosaic map class with some overlap in species. The photo signature for this type was usually brown or gray corresponding to the dryness of the site and the color of the substrates.

Ground Photos

Mesic Herbaceous Vegetation

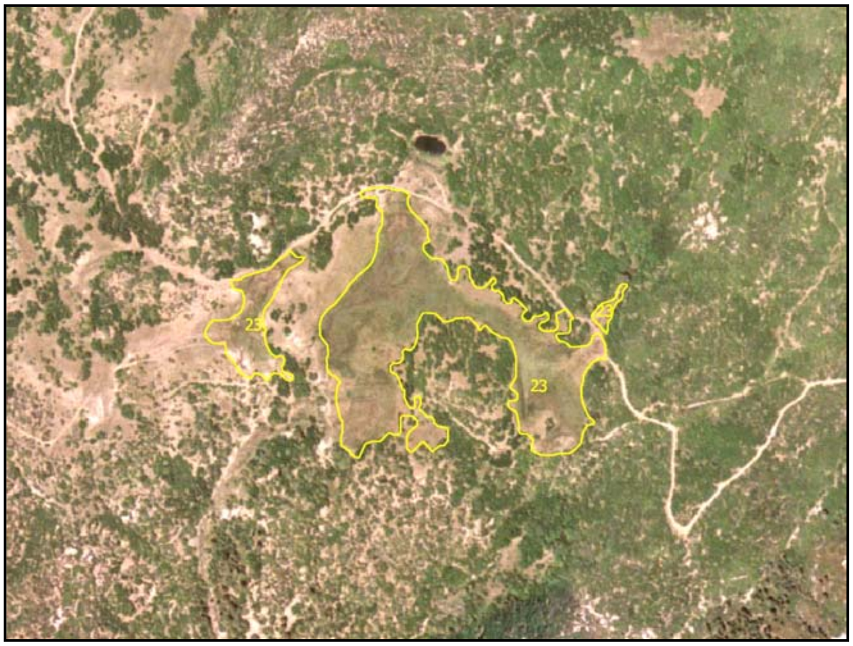
23 *Carex spp.- Juncus spp.* Wet Meadow Herbaceous Vegetation Mosaic
Sedge-Rush Wet Meadow Herbaceous Vegetation Mosaic

Associations:
-*Carex utriculata* Herbaceous Vegetation
-*Carex nebrascensis* Herbaceous Vegetation
-*Equisetum (arvense, variegatum)* Herbaceous Vegetation
-*Juncus balticus* Herbaceous Vegetation

Common species:
Carex utriculata
Carex nebrascensis
Equisetum arvense
Equisetum variegatum
Juncus balticus

Project Specifics:
Frequency = 384 total polygons
68 polygons ZION, 316 polygons Environs
Area = 866 total acres
102 acres ZION, 764 acres Environs
Average Size = 2 acres

Photo Signature Example



Description:
Wet meadows common in the mid and higher elevations of ZION contain a very intricate mix of mesic graminoids. Typically this type appears green on the aerial photos with slender drainages weaving through the site. The lack of shrubs and trees helps identify and delineate this map class from the surrounding vegetation.

Ground Photos

Wetland Herbaceous Vegetation

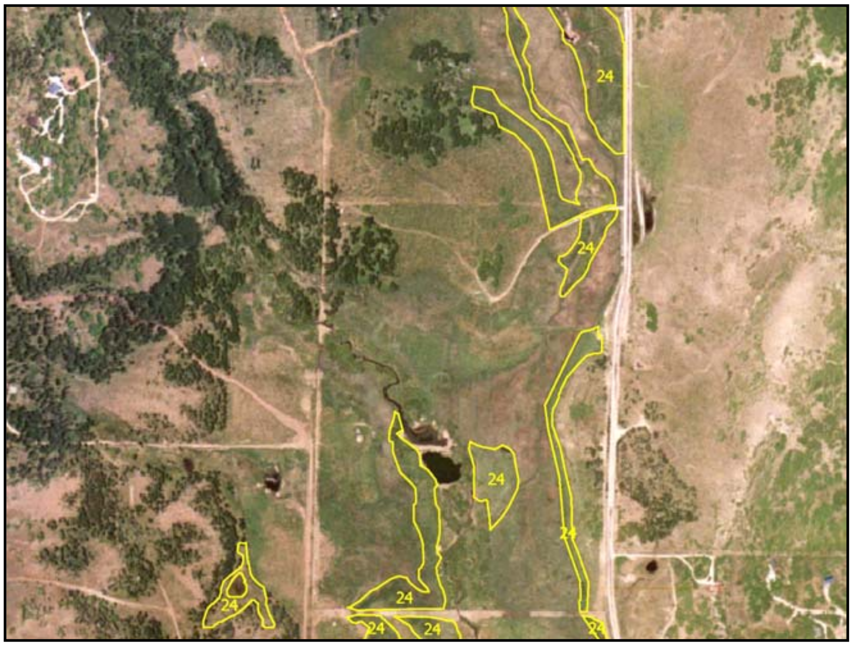
24 *Typha spp., Scirpus spp.* Emergent Wetland Complex
Cattail, Bulrush, Emergent Wetland Complex

Association:
(none; too infrequent to classify)

Common species:
Typha spp.
Scirpus spp.
Carex spp.

Project Specifics:
Frequency = 73 total polygons
2 polygons ZION, 71 polygons Environs
Area = 121 total acres
3 acres ZION, 119 acres Environs
Average Size = 2 acres

Photo Signature Example



Description:
This map class is very rare in the project area and only occurs adjacent to man-made water bodies such as stock ponds and canals. This type usually contains many of the same species as the Sedge-Rush Wet Meadow Herbaceous Vegetation Mosaic map class. The vast majority of this type occurs in the environs. The photo signature is bright green, rough in texture, and may have braided streams or standing water.

Ground Photo

Xeric Shrublands

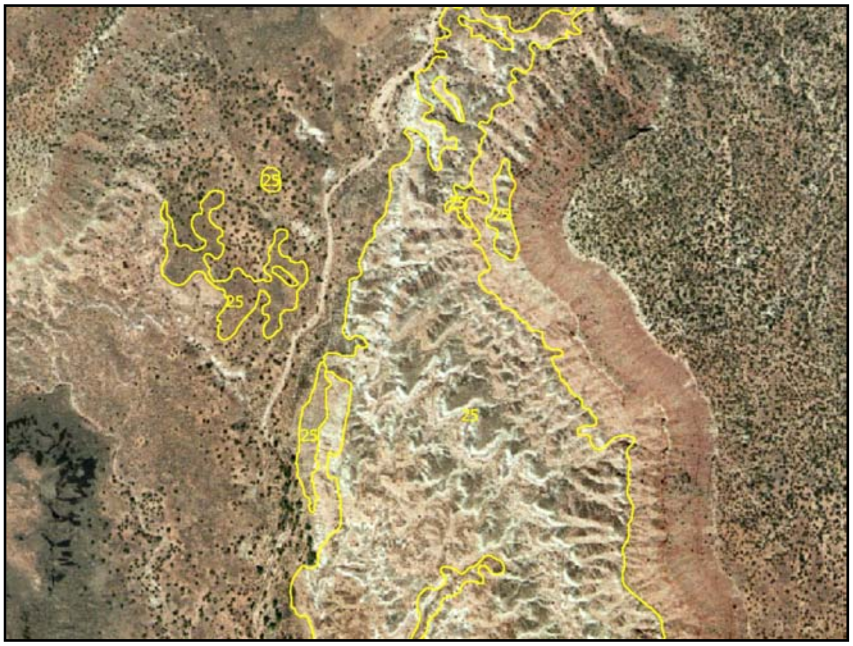
25 *Coleogyne ramosissima* Shrubland Complex
Blackbrush Shrubland Complex

Associations:
-Atriplex canescens Shrubland
-Coleogyne ramosissima Shrubland
-Coleogyne ramosissima / Pleuraphis jamesii Shrubland

Common species:
Atriplex canescens
Coleogyne ramosissima
Pleuraphis jamesii
Gutierrezia sarothrae

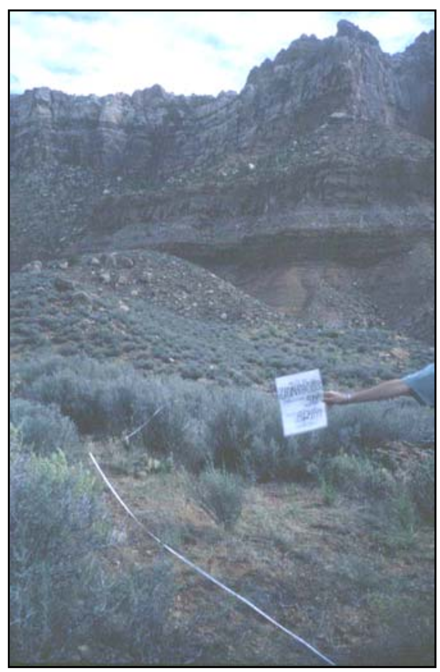
Project Specifics:
Frequency = 173 total polygons
69 polygons ZION, 104 polygons Environs
Area = 1791 total acres
681 acres ZION, 1,110 acres Environs
Average Size = 10 acres

Photo Signature Example



Description:
This is a common semi-arid shrubland found extensively throughout the southern half of ZION and the project's environs. This map class can vary dramatically in density depending on substrate and moisture. In more mesic areas this class can appear dark gray due to the high density of shrubs. Conversely in dry sites, this type will only appear as small gray stipples overwhelmed by the red, white, or brown color of the substrate. Other marginal desert shrubs such as big sagebrush, matchbrush snake weed, and saltbush may exist either as co-dominants or intermixed with this map class.

Ground Photos



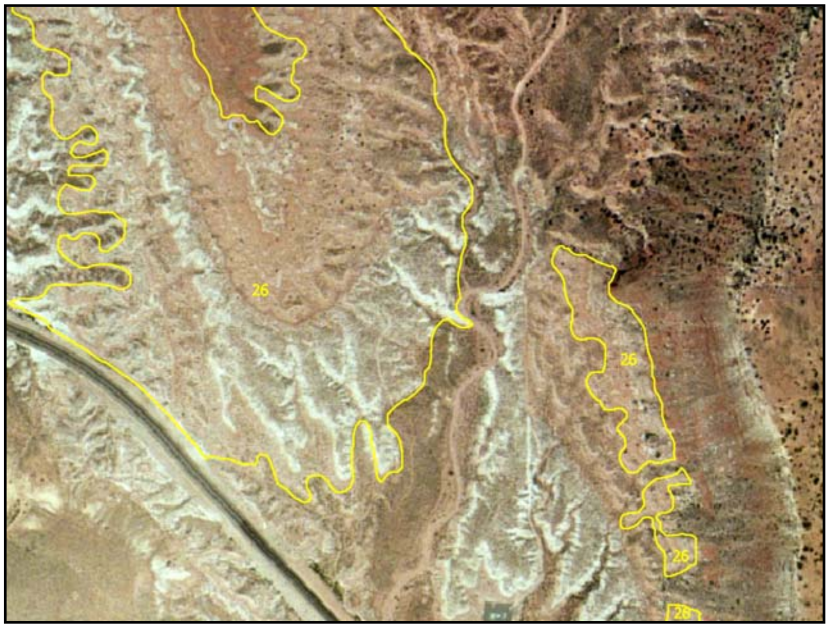
26 *Ephedra nevadensis - Eriogonum corymbosum* Badlands Sparse Vegetation
Painted Desert Sparsely Vegetated Alliance

Associations:
(PAINTED DESERT SPARSELY VEGETATED ALLIANCE)
-*Ephedra nevadensis* / Lichen Sparse Vegetation
-*Eriogonum corymbosum* Badlands Sparse Vegetation

Common species:
Eriogonum corymbosum
Ephedra nevadensis
Bromus tectorum
Atriplex canescens
Atriplex confertifolia
Ericameria nauseosa
Elymus elymoides
Pleuraphis jamesii
Unknown lichen species

Project Specifics:
Frequency = 63 total polygons
24 polygons ZION, 39 polygons Environs
Area = 664 total acres
410 acres ZION, 254 acres Environs
Average Size = 11 acres

Photo Signature Example



Description:
Badlands related to the Chinle geologic formations are relatively rare at ZION. Occurring only in the southern-most portions of the project area, this map class is very dry but does support a mix of xeric shrubs and forbs. On the photos this type looked similar to sparse forms of the Blackbrush Shrubland Complex and to the barren Chinle geology map classes.

Ground Photos

27 *Ephedra nevadensis* Basalt Shrubland
Nevada Joint-fir Basalt Shrubland

Photo Signature Example

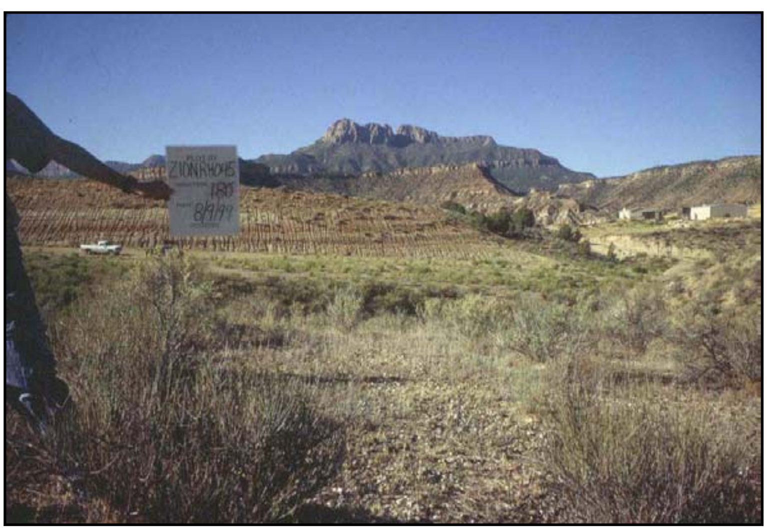
Association:
-Ephedra nevadensis Basalt Shrubland

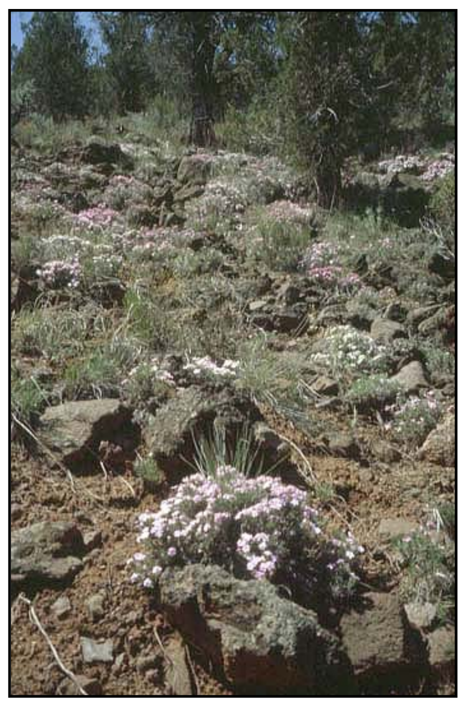
Common species:
Eriogonum corymbosum
Ephedra nevadensis
Bromus tectorum
Atriplex canescens
Atriplex confertifolia
Ericameria nauseosa
Elymus elymoides
Pleuraphis jamesii
Unknown lichen species

Project Specifics:
Frequency = 36 total polygons
12 polygons ZION, 24 polygons Environs
Area = 453 total acres
201 acres ZION, 252 acres Environs
Average Size = 13 acres

Description:
This map class is very similar in species composition to the Painted Desert Sparsely Vegetated Alliance map class although it occurs on a dramatically different substrate, volcanic basalt. The black color of substrate allowed for relatively straight-forward interpretation of this map class from the aerial photos. In extremely sparse stands, this map class may have been mapped as barren basalt outcrop or volcanic cinders.

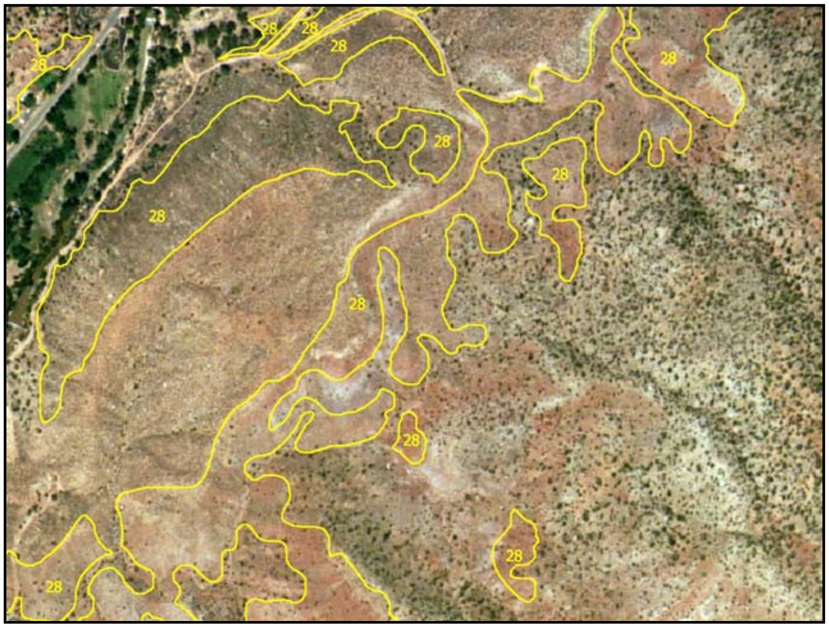
Ground Photos





28 *Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii* Dwarf-shrubland
Snakeweed - (Prickly-pear species) / James' Galleta Dwarf-shrubland

Photo Signature Example



Associations:
-Gutierrezia sarothrae - (Opuntia spp.) / Pleuraphis jamesii Dwarf-shrubland

Common species:
Gutierrezia sarothrae
Opuntia spp.
Pleuraphis jamesii
Bromus tectorum
Elymus elymoides,

Project Specifics:
Frequency = 412 total polygons
232 polygons ZION, 180 polygons Environs
Area = 1,846 total acres
642 acres ZION, 1,205 acres Environs
Average Size = 4.7 acres

Description:
This map class occurs in many harsh habitats throughout ZION including old fields, pastures, arid sandy deposits and south-facing slopes. Disturbance may be important in maintaining this map class, as some stands have been created by removal of trees and grazing by livestock. The scarcity of cover in this type likely makes it appear as other arid, herbaceous and barren map classes.

Ground Photos

29 *Prosopis juliflora* Shrub Stands
Honey Mesquite Shrub Stands

Photo Signature Example

Associations:
(none; too small to classify)

Common species:
Prosopis juliflora

Project Specifics:
Frequency = 6 total polygons
0 polygons ZION, 6 polygons Environs
Area = 2 total acres
0 acres ZION, 2 acres Environs
Average Size = 0.3 acres

Description:
Stands of mesquite only occurred in 6 documented sites all outside the boundary of ZION. Here, each stand was comprised of a handful of individual tall shrubs. This type was mapped solely from field observations and GPS points.

Ground Photo

Upland Shrublands

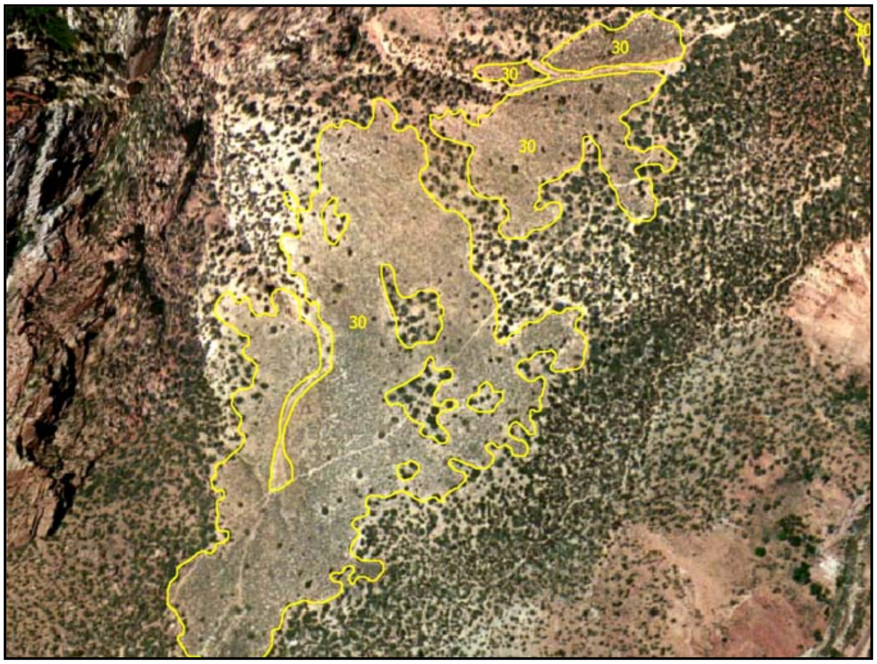
30 *Artemisia filifolia* Colorado Plateau Shrubland
Sand Sagebrush Colorado Plateau Shrubland

Association:
-*Artemisia filifolia* Colorado Plateau Shrubland

Common species:
Artemisia filifolia
Bromus tectorum
Sporobolus cryptandrus

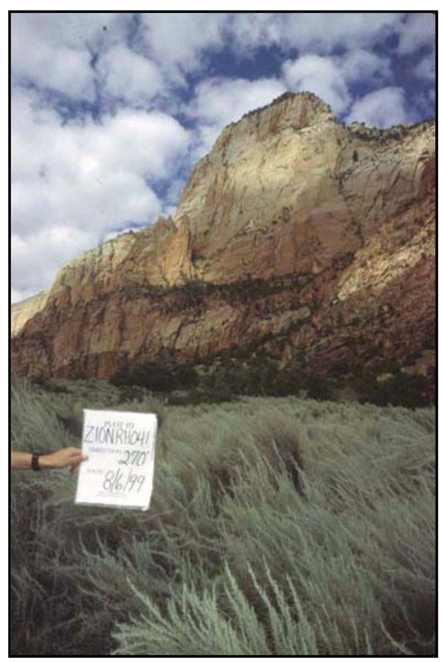
Project Specifics:
Frequency = 43 total polygons
41 polygons ZION, 2 polygons Environs
Area = 127 total acres
124 acres ZION, 3 acres Environs
Average Size = 3 acres

Photo Signature Example



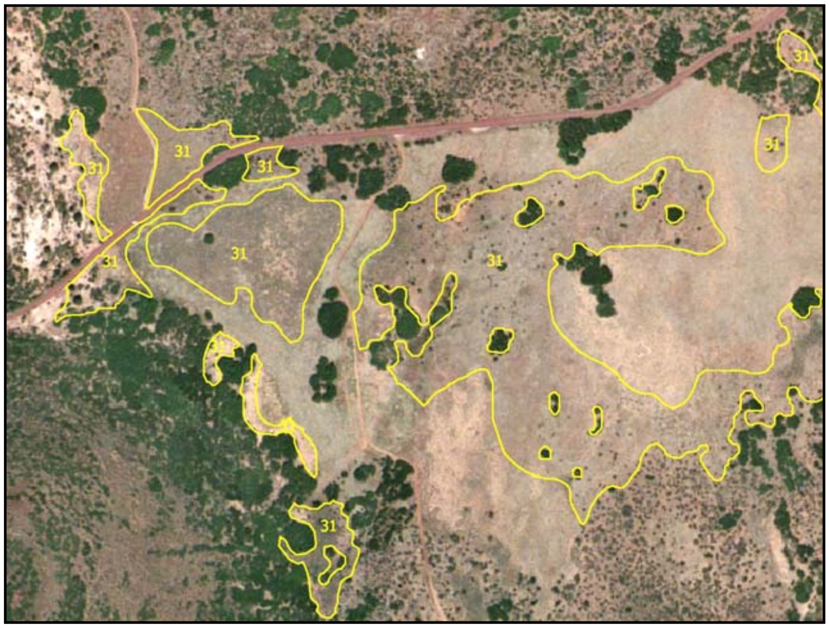
Description:
This map class was fairly rare at ZION, only occurring in a few sandy deposits in the southern half of the Park. Sand sagebrush was also present in other sagebrush and shrub map classes but only as a minor component. One large sand deposit in the main canyon (pictured above) represented a majority of the area covered by this type. Other sagebrush types likely intermingle with this map class, appearing similar on the aerial photos.

Ground Photos



31 *Artemisia tridentata* Shrubland Complex
Big Sagebrush Shrubland Complex

Photo Signature Example



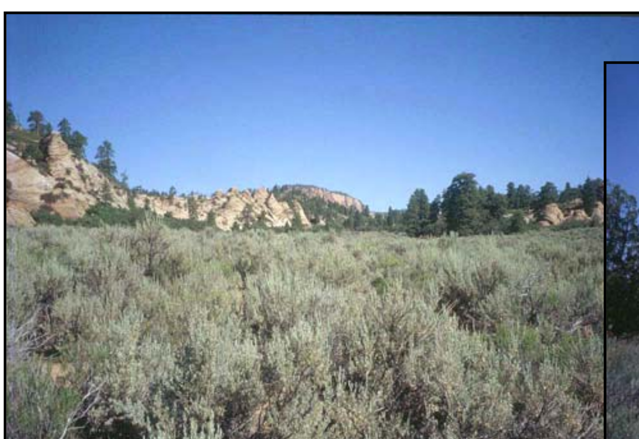
Associations:
-*Artemisia tridentata / Bouteloua gracilis* Shrubland
-*A. tridentata - (Ericameria nauseosa) / Bromus tectorum* Shrubland
-*A. tridentata ssp. tridentata / Pascopyrum smithii - (Elymus lanceolatus)* Shrubland
-*Artemisia tridentata ssp. vaseyana / Hesperostipa comata* Shrubland
-*Atriplex canescens - Artemisia tridentata* Shrubland
-*Tetradymia canescens - Ephedra viridis* Shrubland

Common species:
Artemisia tridentata ssp. tridentata
Artemisia tridentata ssp. vaseyana
Atriplex canescens
Elymus lanceolatus
Ericameria nauseosa
Bouteloua gracilis
Tetradymia canescens
Ephedra viridis
Hesperostipa comata

Project Specifics:
Frequency = 1,408 total polygons
628 polygons ZION, 780 polygons Environs
Area = 6,745 total acres
2,201 acres ZION, 4,544 acres Environs
Average Size = 5 acres

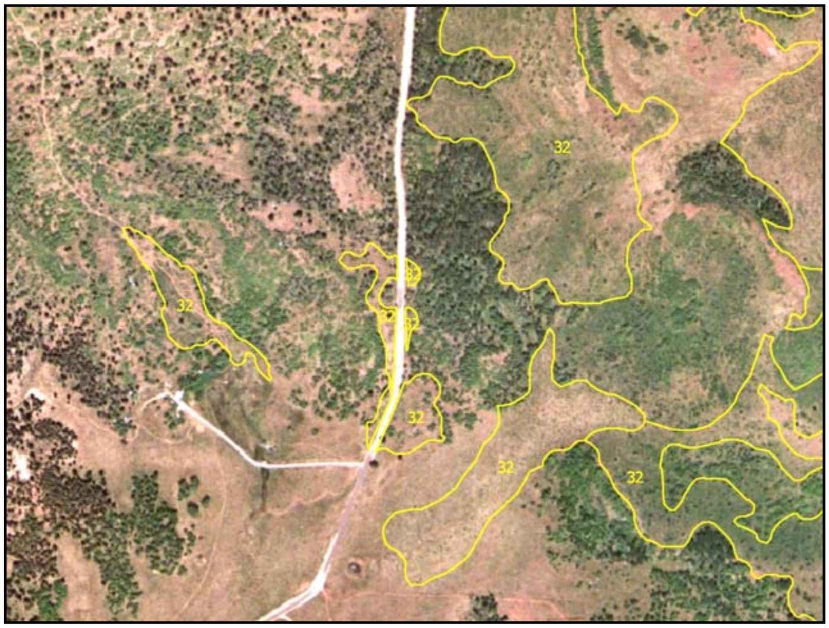
Description:
Big sagebrush is widespread through the Park shifting from the basin big sagebrush subspecies (spp. *tridentata*) in the south to mountain big sagebrush (spp. *vaseyana*) in the middle and northern portions. The gray color of the sagebrush is readily apparent on the aerial photos but is very similar to other sagebrushes (i.e. sand, black). Due to extreme similarities in height, color, and habitat, spineless horsebrush could not be separated from big sagebrush. Instead, horsebrush was combined with big sagebrush to form a complex, which closely matches their tendency to intermix on the ground as well.

Ground Photos



32 *Ericameria (Chrysothamnus) spp.* Shrubland Complex
Rabbitbrush Shrubland Complex

Photo Signature Example



Associations:
-Chrysothamnus viscidiflorus / Poa pratensis Shrub Herbaceous Vegetation [Provisional]
-Ericameria nauseosa / Bromus tectorum Shrubland
-Ericameria nauseosa Slide Deposit Sparse Vegetation

Common species:
Chrysothamnus viscidiflorus
Ericameria nauseosa
Poa pratensis
Artemisia tridentata
Gutierrezia sarothrae
Opuntia spp.
Pleuraphis jamesii

Project Specifics:
Frequency = 438 total polygons
197 polygons ZION, 241 polygons Environs
Area = 1,087 total acres
357 acres ZION, 730 acres Environs
Average Size = 2 acres

Description:
This map class combined two species of rabbitbrush into one map class in order to increase accuracy and reduce confusion in their signatures. *Chrysothamnus viscidiflorus* was more common in the northern half of the Park and *Ericameria nauseosa* was found throughout, mainly on disturbed early seral sites. On the aerial photos, the signature varied depending on density and substrate. When rabbitbrush was dense, a green signature was given; in sparse situations the color of the substrate was more prevalent. The location of the signature in and next to disturbed sites such as old agricultural fields and roadways helped to delineate this type.

Ground Photos

33 *Cercocarpus intricatus Slickrock* Sparse Vegetation
Littleleaf Mountain-mahogany Slickrock Sparse Vegetation

Association:
-*Cercocarpus intricatus* Slickrock Sparse Vegetation

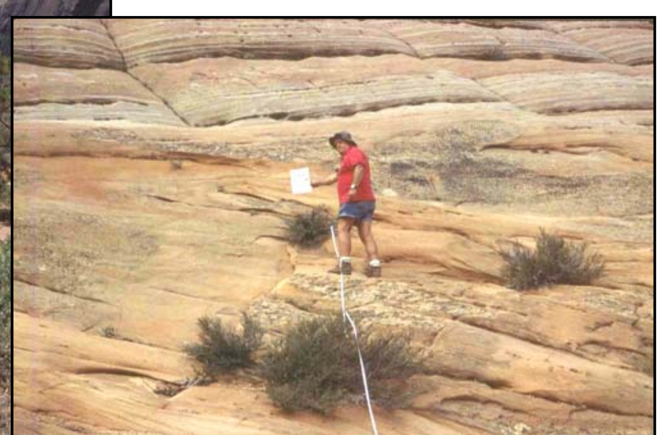
Common species:
Cercocarpus intricatus
Arctostaphylos patula
Pinus ponderosa
Pinus edulis
Purshia stansburiana

Project Specifics:
Frequency = 1,248 total polygons
1,049 polygons ZION, 199 polygons Environs
Area = 4,631 total acres
3,723 acres ZION, 908 acres Environs
Average Size = 4 acres

Photo Signature Example

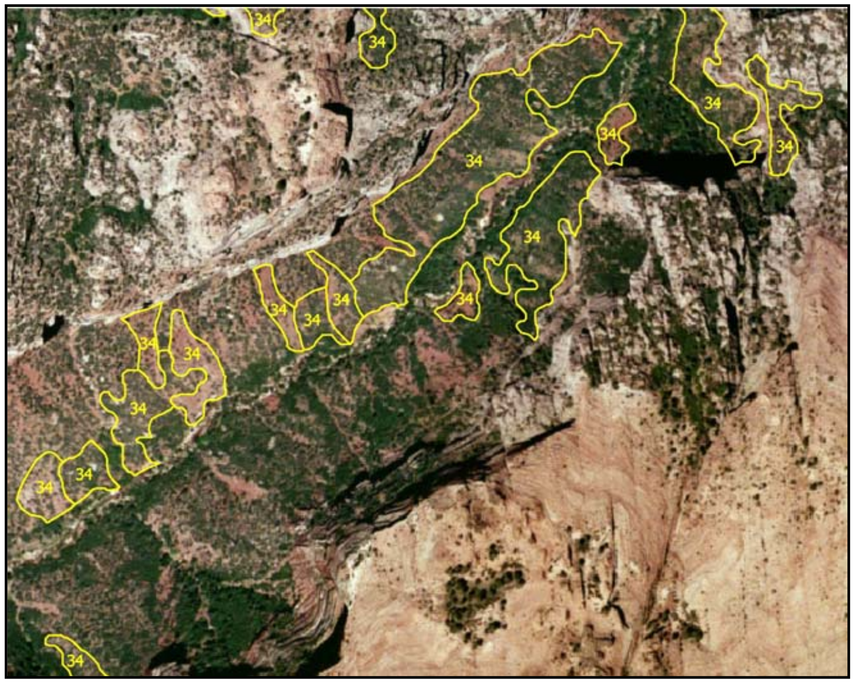
Description:
This widespread map class was found throughout the Navajo, slickrock portions of ZION. This type was extremely sparse, occurring in rock crevices, canyon walls, and small ledges. Other shrubs such as manzanita and cliff-rose may be present and partially distort the photo signature. Extremely sparse stands of ponderosa pine and pinyon pine may also intermingle with this map class.

Ground Photos



34 *Quercus turbinella - (Amelanchier utahensis)* Colluvial Shrubland
Talus Mixed Shrubland

Photo Signature Example



Association:
-Quercus turbinella - (Amelanchier utahensis) Colluvial Shrubland

Common species:
Quercus turbinella
Amelanchier utahensis
Juniperus osteosperma
Pinus edulis
Shepherdia rotundifolia

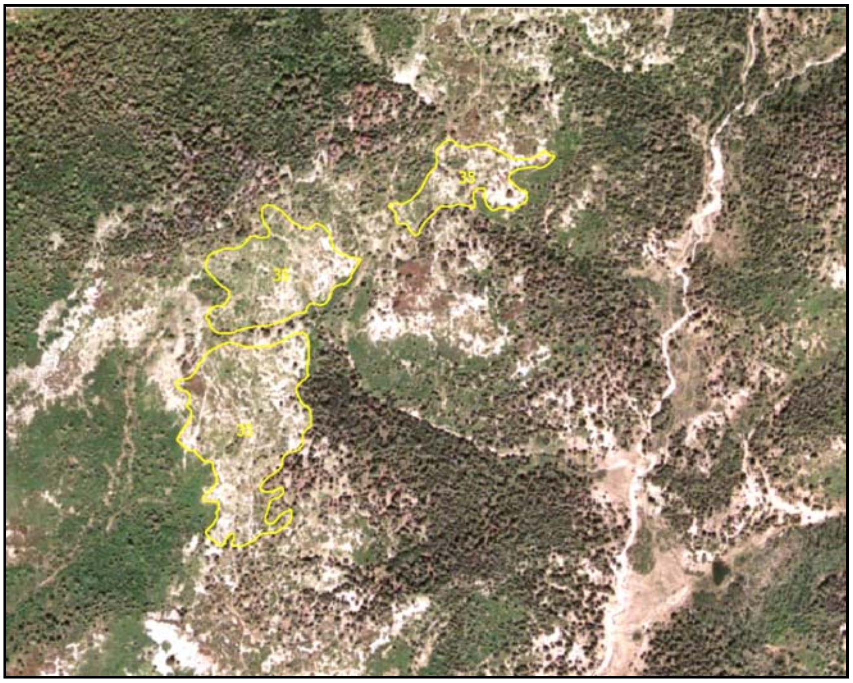
Project Specifics:
Frequency = 871 total polygons
784 polygons ZION, 87 polygons Environs
Area = 3,114 total acres
2,796 acres ZION, 871 acres Environs
Average Size = 4 acres

Description:
The live oak map class occurred throughout the Park on rocky, colluvial slopes (mainly toe and foot slopes). It was especially prevalent on the talus fields below the Navajo sandstone formation. The density and height of this shrub varied with aspect, substrate, and moisture; ranging from tall, thick shrubs to stunted, sparse communities. It also tended to intermix with pinyon – juniper types forming a prevalent understory in many cases. In the north, live oak mixed with other shrubs to form the mixed mountain shrubland map class. This map class appeared gray on the aerial photos that may have resulted in it being confused with other gray shrubs such as serviceberry and sagebrush.

Ground Photos

35 *Symphoricarpos oreophilus / Poa pratensis* Semi-natural Shrubland
Mountain Snowberry / Kentucky Bluegrass Semi-natural Shrubland

Photo Signature Example



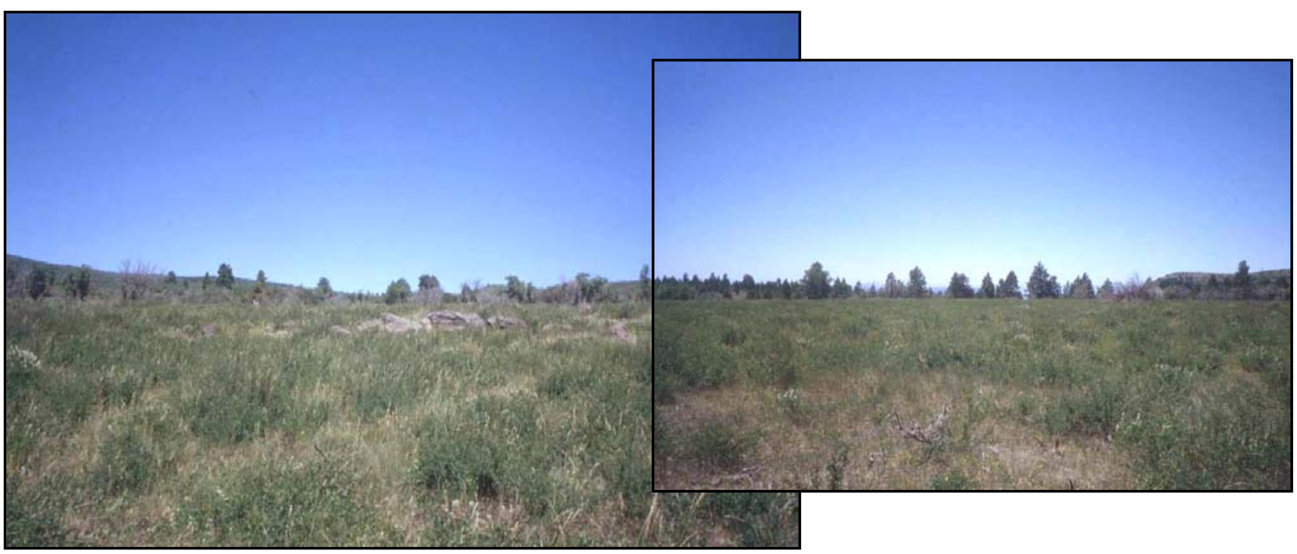
Associations:
-*Symphoricarpos oreophilus / Poa pratensis* Semi-natural Shrubland

Common species:
Symphoricarpos oreophilus
Poa pratensis
Quercus gambelii

Project Specifics:
Frequency = 68 total polygons
43 polygons ZION, 25 polygons Environs
Area = 281 total acres
186 acres ZION, 95 acres Environs
Average Size = 4 acres

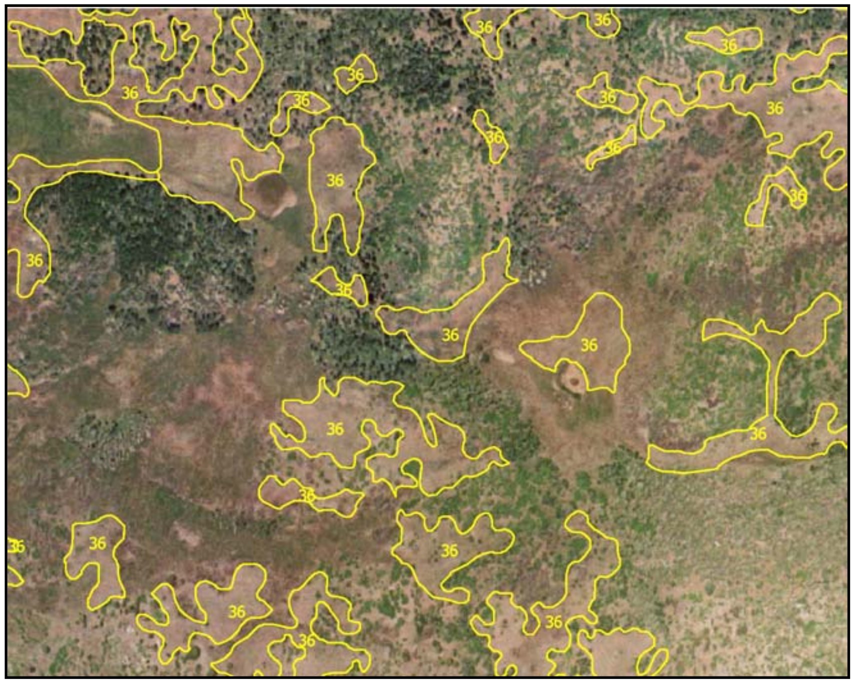
Description:
Typically this map class occurred on post-fire sites where the intensity of the fire appeared to completely burn off the shrub and tree layers. Also, mountain snowberry appeared to occur on primarily white substrates belonging to the Carmel geologic formation. The shrubs appeared green on the aerial photos and this coupled with post-burn evidence and white substrates helped locate and delineate this type. Gambel oak and other deciduous shrubs appearing green on the photography looked similar to this map class and may have led to some omission error.

Ground Photos



36 *Artemisia nova Dwarf-shrubland* Complex
Black Sagebrush Dwarf-shrubland Complex

Photo Signature Example



Associations:
-Artemisia nova / Elymus elymoides Dwarf-shrubland
-Artemisia nova / Hesperostipa comata Dwarf-shrubland
-Artemisia nova / Poa fendleriana Dwarf-shrubland

Common species:
Artemisia nova
Poa fendleriana
Hesperostipa comata
Elymus elymoides
Poa pratensis

Project Specifics:
Frequency = 214 total polygons
147 polygons ZION, 67 polygons Environs
Area = 909 total acres
464 acres ZION, 446 acres Environs
Average Size = 4 acres

Description:
This dwarf shrubland was common throughout the northern portion of the Park in natural woodland meadows and old agricultural pastures. The low stature of this shrub made this map class appear much like herbaceous types although its gray color helped greatly in distinguishing it from other map classes. Similar shrubs such as stunted mountain big sagebrush may have been mapped as this type in some isolated instances.

Ground Photos

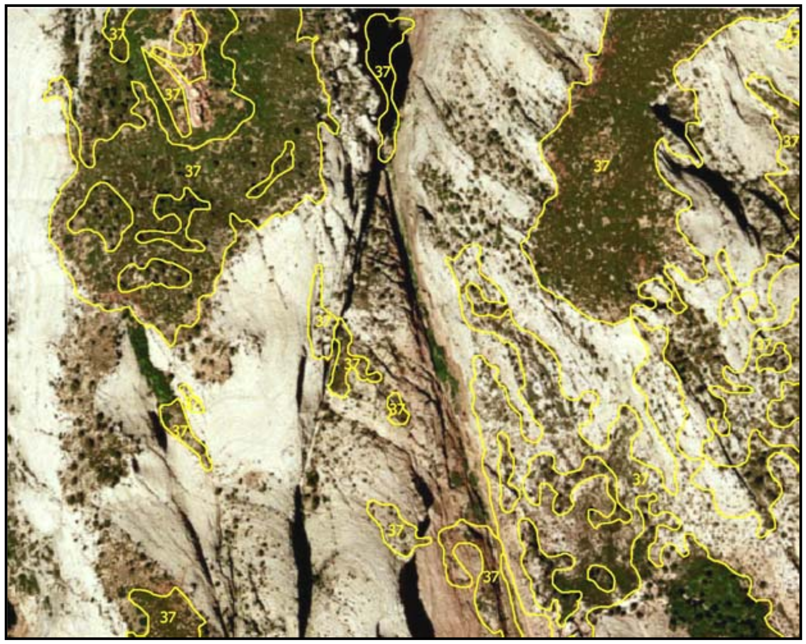
37 *Arctostaphylos patula* Shrubland Complex
Greenleaf Manzanita Shrubland Complex

Associations:
-*Arctostaphylos patula - Artemisia tridentata ssp. vaseyana* Shrubland
-*Arctostaphylos patula* Shrubland
-*Purshia stansburiana - Arctostaphylos patula* Shrubland

Common species:
Arctostaphylos patula
Artemisia tridentata ssp. Vaseyana
Purshia stansburiana
Cercocarpus intricatus

Project Specifics:
Frequency = 2,245 total polygons
1,702 polygons ZION, 543 polygons Environs
Area = 11,022 total acres
7,860 acres ZION, 3,162 acres Environs
Average Size = 5 acres

Photo Signature Example



Description:
Besides gambel oak, greenleaf manzanita was probably the next most common shrub found at ZION during this study. This map class occurred park-wide and in a wide array of diverse habitats ranging from dense stands on plateau tops to sparse, stunted groups on slickrock. The olive green color of greenleaf manzanita really stood out on the true color aerial photography, making for relatively easy interpretation of this type. Some minor confusion may have existed when gambel oak grew in close proximity changing the call to Greenleaf Manzanita - Gambel Oak - (Utah Serviceberry) Shrubland map class. Green-leaf manzanita also occurred as a common understory species with ponderosa pine, often intermixing.

Ground Photos

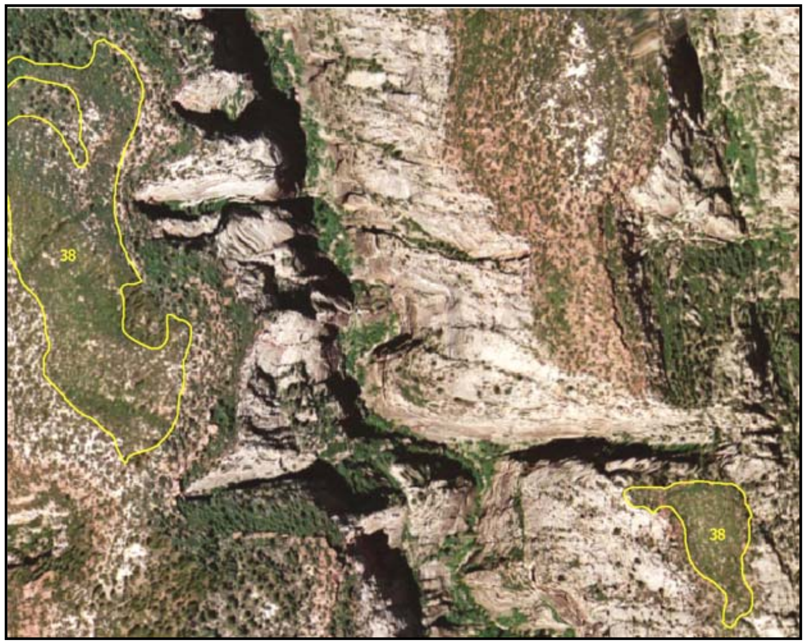
38 *Arctostaphylos patula - Quercus gambelii - (Amelanchier utahensis)* Shrubland
Greenleaf Manzanita - Gambel Oak - (Utah Serviceberry) Shrubland

Association:
Arctostaphylos patula - Quercus gambelii (Amelanchier utahensis) Shrubland

Common species:
Arctostaphylos patula
Quercus gambelii
Amelanchier utahensis

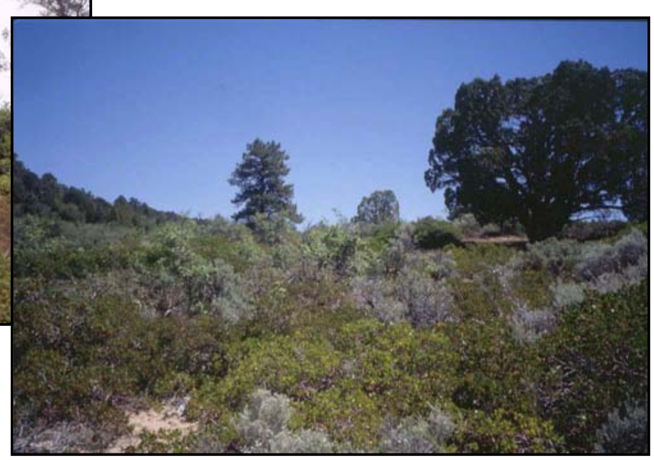
Project Specifics:
Frequency = 185 total polygons
144 polygons ZION, 41 polygons Environs
Area = 1,427 total acres
1,000 acres ZION, 427 acres Environs
Average Size = 8 acres

Photo Signature Example



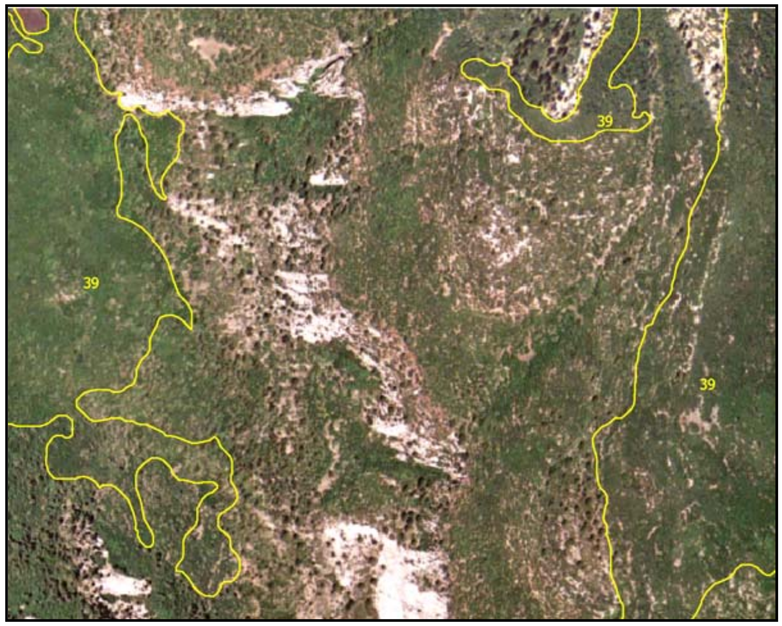
Description:
This map class differed from the Greenleaf Manzanita Shrubland Complex type by the presence of gambel oak and other shrubs. When gambel oak and greenleaf manzanita appeared to occur in stands at roughly 50%-50% cover this map class was used as the label. On the ground, this association tended to occur on more mesic mesa and plateau tops, appearing dense and somewhat diverse.

Ground Photos



39 *Quercus gambelii* Shrubland Alliance
Gambel Oak Shrubland Alliance

Photo Signature Example



Associations:
-Quercus gambelii / Amelanchier utahensis Shrubland
-Quercus gambelii / Artemisia tridentata Shrubland
-Quercus gambelii - Cercocarpus montanus / (Carex geyeri) Shrubland
-Quercus gambelii / Symphoricarpos oreophilus Shrubland
-Quercus gambelii / Poa fendleriana Shrubland

Common species:
Quercus gambelii
Amelanchier utahensis
Artemisia tridentata
Cercocarpus montanus
Symphoricarpos oreophilus
Carex geyeri
Poa fendleriana

Project Specifics:
Frequency = 3,199 total polygons
2,164 polygons ZION, 1,035 polygons Environs
Area = 17,579 total acres
10,990 acres ZION, 6,589 acres Environs
Average Size = 5 acres

Description:
Gambel oak was the most common shrub at ZION in terms of area covered. This widespread map class covered large areas ranging from mesic valley floors to broad post-fire mesa tops. The true green color of this shrub was very evident on the aerial photos, providing relatively straight-forwared interpretation.

Ground Photos

40 *Mixed Mountain* Shrubland Complex
Mixed Mountain Shrubland Complex

Associations:
-*Arctostaphylos pungens* Shrubland
-*Arctostaphylos patula - Artemisia tridentata ssp. vaseyana* Shrubland *
-*Arctostaphylos patula* Shrubland *
-*Purshia stansburiana - Arctostaphylos patula* Shrubland*
-*Quercus turbinella - (Amelanchier utahensis)* Colluvial Shrubland *
-*Cercocarpus montanus* Rock Pavement Sparse Vegetation

Common species:
Arctostaphylos pungens
Arctostaphylos patula
Artemisia tridentata ssp. vaseyana
Purshia stansburiana
Quercus turbinella
Amelanchier utahensis
Cercocarpus montanus

Project Specifics:
Frequency = 1,134 total polygons
720 polygons ZION, 414 polygons Environs
Area = 6,518 total acres
3,986 acres ZION, 2,532 acres Environs
Average Size = 6 acres

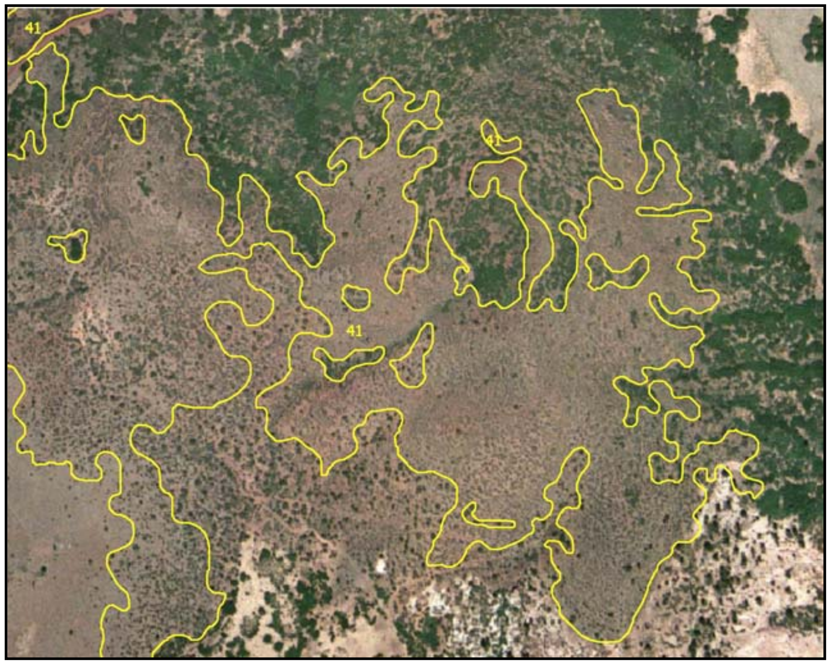
Photo Signature Example

Description:
The Mixed Mountain Shrubland Complex represents an unique map unit that occurs in the northern portions of ZION. This map unit contains an intricate mix of both an unique shrub association (*Arctostaphylos pungens* Shrubland) and other more common shrub associations at ZION (denoted by *). Habitat characteristics for this type includes rocky or colluvial substrates, moderately mesic conditions and close proximity to other shrub and pinyon – juniper map classes. This map unit likely represents a broad ecotone containing many common species. On the aerial photos this type is represented by a gray stippled signature caused by the presence of tall shrubs.

Ground Photos

41 *Amelanchier utahensis* Shrubland
Utah Serviceberry Shrubland

Photo Signature Example



Association:
-*Amelanchier utahensis* Shrubland

Common species:
Amelanchier utahensis
Artemisia tridentata

Project Specifics:
Frequency = 86 total polygons
75 polygons ZION, 11 polygons Environs
Area = 593 total acres
462 acres ZION, 132 acres Environs
Average Size = 7 acres

Description:

Pure Utah serviceberry stands were relatively rare at ZION even though the species was a common component in many other shrubland map classes. Typically this type occurred on the slopes of volcanic cinder cones and on cinder fields appearing as regular spaced gray dots. Other tall shrubland map classes, especially the Mixed Mountain Shrubland Complex may have been confused with this type where the they intermix.

Ground Photos

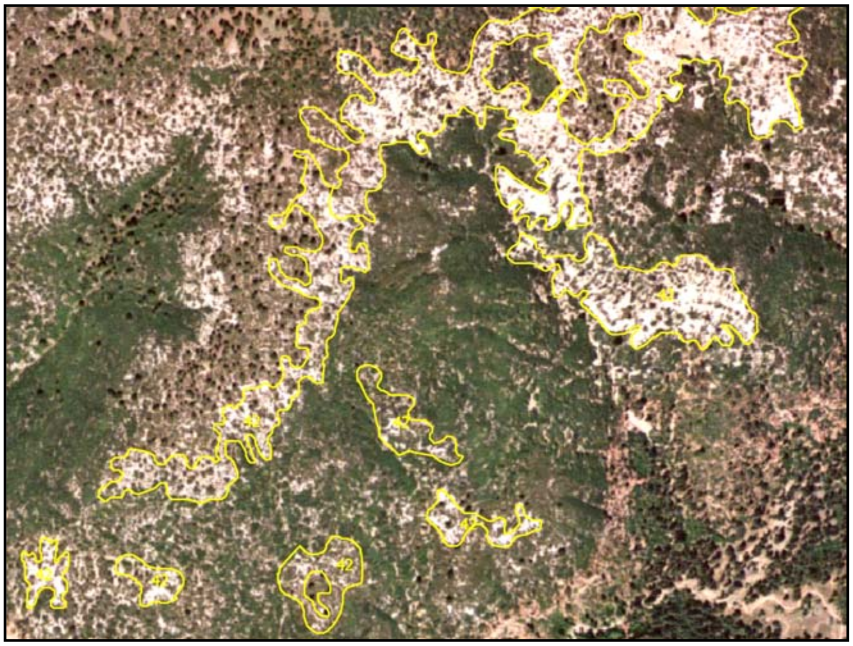
42 *Cercocarpus montanus* Rock Pavement Sparse Vegetation
Mountain-mahogany Rock Pavement Sparse Vegetation

Association:
-Cercocarpus montanus Rock Pavement Sparse Vegetation

Common species:
Cercocarpus montanus
Arctostaphylos patula
Quercus gambelii
Amelanchier utahensis

Project Specifics:
Frequency = 128 total polygons
60 polygons ZION, 68 polygons Environs
Area = 744 total acres
295 acres ZION, 449 acres Environs
Average Size = 6 acres

Photo Signature Example



Description:
At ZION, exposed Carmel geologic formations form a characteristic white cap in some of the highest portions of the Park. On this rugged terrain stunted mountain mahogany shrubs form unique associations that were observable on the aerial photography. In fact, the white substrate helped locate and delineate this type and is included in the naming of the association.

Ground Photos

Riparian Shrublands

43 *Baccharis emoryi* Shrubland
Emory Seepwillow Shrubland

Photo Signature Example

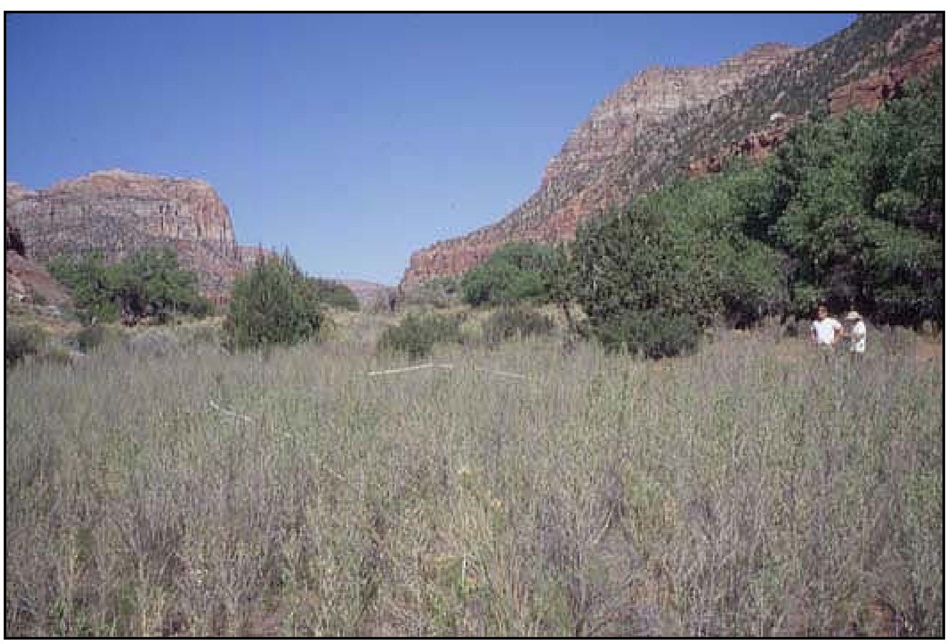
Associations:
-*Baccharis emoryi* Shrubland

Common species:
Baccharis emoryi
Equisetum variegatum
Melilotus officinalis
Salsola tragus
Muhlenbergia asperifolia
Poa pratensis

Project Specifics:
Frequency = 121 total polygons
96 polygons ZION, 25 polygons Environs
Area = 66 total acres
53 acres ZION, 13 acres Environs
Average Size = 0.5 acres

Description:
Seepwillow was common in Zion Canyon and along other streams in the southern portion of the project area growing on flat streambanks or stream terraces. In these situations, this map class often occurred in a mosaic amongst mature *Populus fremontii - Fraxinus velutina* Woodland. On the aerial photos, seepwillow ranged from green to gray depending on amount of leaf cover. The location of this type on sandbars and sandy beaches helped locate and delineate it.

Ground Photo



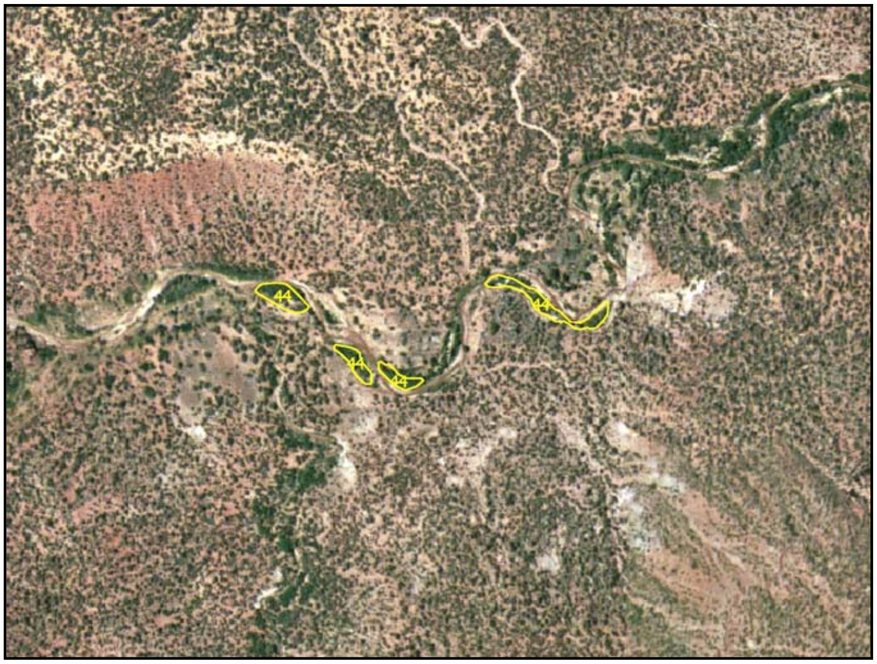
44 *Salix exigua* Shrubland Alliance
Sandbar Willow Shrubland Alliance

Associations:
SALIX (EXIGUA, INTERIOR)
TEMPORARILY FLOODED SHRUBLAND ALLIANCE
-*Salix exigua* / Barren Shrubland
-Salix exigua / Mesic Graminoids Shrubland

Common species:
Salix exigua
Agrostis stolonifera
Bromus tectorum
Juncus longistylis
Artemisia campestris
Rumex acetosella
Senecio spartioides

Project Specifics:
Frequency = 60 total polygons
52 polygons ZION, 8 polygons Environs
Area = 40 total acres
35 acres ZION, 6 acres Environs
Average Size = 0.7 acres

Photo Signature Example



Description:
Sandbar willow was common throughout the Park on sandy soils adjacent to streams and rivers. This particular map class was reserved for stands occurring in the middle and northern portions of the Park were it grew without seepwillow. In the south, particularly in Zion Canyon, sandbar willow usually occurred with seepwillow and was mapped using the Emory Seepwillow Shrubland designation. On the aerial photos, sandbar willow ranged from green to gray depending on amount of leaf cover. The location of this type on sandbars and sandy beaches helped locate and delineate it.

Ground Photos

45 *Tamarix* spp. Temporarily Flooded Shrubland
Tamarisk spp. Temporarily Flooded Shrubland

Photo Signature Example

Associations:
-*Tamarix* spp. Temporarily Flooded Shrubland

Common species:
Tamarix ramosissima
Salix exigua
Baccharis emoryi
Populus fremontii
Elaeagnus angustifolia

Project Specifics:
Frequency = 128total polygons
10 polygons ZION, 118 polygons Environs
Area = 199 total acres
3 acres ZION, 199 acres Environs
Average Size = 2 acres

Description:
This non-native map class was found primarily outside of ZION along the Virgin River floodplain. Tamarisk tended to form dense stands that were characterized with a dark green signature. Other floodplain and riparian map classes tended to intermingle with this type. In the Park this type was limited to some isolated stands in the South due to an active control and eradication program.

Ground Photo

46 *Pluchea sericea* Seasonally Flooded Shrubland
Arrow-weed Seasonally Flooded Shrubland

Photo Signature Example

Association:
-Pluchea sericea Seasonally Flooded Shrubland

Common species:
Pluchea sericea
Gutierrezia sarothrae
Sporobolus cryptandrus
Melilotus officinalis

Project Specifics:
Frequency = 3 total polygons
0 polygons ZION, 3 polygons Environs
Area = 8 total acres
0 acres ZION, 8 acres Environs
Average Size = 3 acres

Description:
This type was very rare in the project area occurring in only 2 stands large enough to map. In these situations, arrow-weed was clearly the dominant covering most of the site. Some exotic species were present likely due to exposure to human and/or livestock disturbance. This map class was located and delineated from field observations and GPS locations.

Ground Photo

47 *Salix ligulifolia / Carex utriculata* Shrubland
Strapleaf Willow / Beaked Sedge Shrubland

Association:
-Salix ligulifolia / Carex utriculata
Shrubland

Common species:
Salix ligulifolia
Carex utriculata
Poa pratensis
Maianthemum stellatum

Project Specifics:
Frequency = 24 total polygons
5 polygons ZION, 19 polygons Environs
Area = 39 total acres
5 acres ZION, 34 acres Environs
Average Size = 2 acres

Photo Signature Example

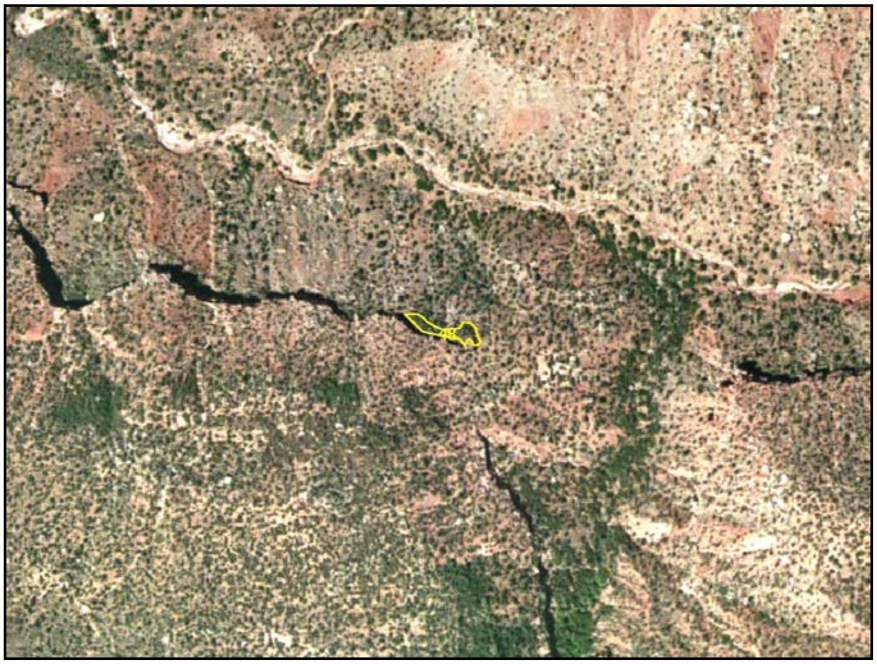
Description:
Strapleaf willow occurred in isolated patches in the northern-most reaches of the projects area in high elevations. This map class was fairly rare but was distinctive as tall, light green - gray shrubs. The wet meadow habitat of this type also helped with locating and separating it from other deciduous shrubs. This type tended to grow in isolated stands and some very small patches may have been overlooked in the photo interpretation.

Ground Photo

Riparian Woodlands

48 *Fraxinus anomala* Woodland
Single-leaf Ash Woodland

Photo Signature Example



Association:
-Fraxinus anomala Woodland

Common species:
Fraxinus anomala
Quercus gambelii
Amelanchier alnifolia
Ericameria nauseosa
Rhus trilobata

Project Specifics:
Frequency = 1 total polygons
1 polygons ZION, 0 polygons Environs
Area = 0.9 total acres
0.9 acres ZION, 0 acres Environs
Average Size = 0.9 acres

Description:
Single-leaf ash stands big enough to map were extremely rare in this project. Single-leaf was fairly common as a shrub or sub-canopy component in many other riparian and deciduous woodlands but was not found very often as a true association. This type was likely confused with gambel oak shrubland and other deciduous shrubland map classes. The one polygon mapped was based off the only known plot location.

Ground Photo

49 *Acer negundo* Woodland Alliance
Boxelder Woodland Alliance

Associations:
-*Acer negundo* / Brickellia grandiflora Woodland
-*Acer negundo* / Disturbed Understory Wodland

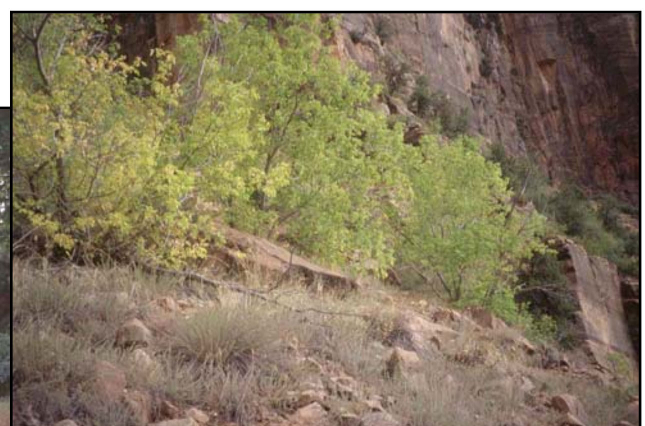
Common species:
Acer negundo
Brickellia grandiflora
Bromus tectorum

Project Specifics:
Frequency = 44 total polygons
42 polygons ZION, 2 polygons Environs
Area = 69 total acres
67 acres ZION, 1 acre Environs
Average Size = 2 acres

Photo Signature Example

Description:
This rare map class occurs mainly in the Park as small stands along waterways and on floodplains. Boxelder is one of the more prominent riparian tree species at ZION, especially in the lower elevations of the Park. Boxelder is also fairly abundant in other mixed deciduous stands but its foliage is identical to cottonwood, velvet ash, and other deciduous trees on the true-color aerial photos. This type was mapped in known areas based on ground observations, plot and observation point locations, and in areas that had very similar habitat.

Ground Photos



50 *Populus fremontii* Woodland Complex
Fremont Cottonwood Woodland Complex

Photo Signature Example

Associations:
-Populus fremontii / Betula occidentalis Wooded Shrubland
-Populus fremontii / Salix exigua Forest
-Populus fremontii / Baccharis emoryi Woodland

Common species:
Populus fremontii
Salix exigua
Betula occidentalis
Baccharis emoryi
Ericameria nauseosa
Bromus diandrus
Bromus tectorum
Muhlenbergia asperifolia
Melilotus officinalis

Project Specifics:
Frequency = 390 total polygons
126 polygons ZION, 264 polygons Environs
Area = 669 total acres
425 acres ZION, 244 acres Environs
Average Size = 2 acres

Description:
This is a fairly common map class at ZION, typical of the Virgin River Floodplain and in other prominent drainages. The photo signature of this type varies from dark lush green to gray-brown depending on the age, height, and health of the trees. In most cases this type occurs intermixed with other riparian and floodplain map classes like Mixed Riparian Woodlands and Sandbar Willow Shrublands. This map class may be confused on the photos with other deciduous woodland types.

Ground Photos

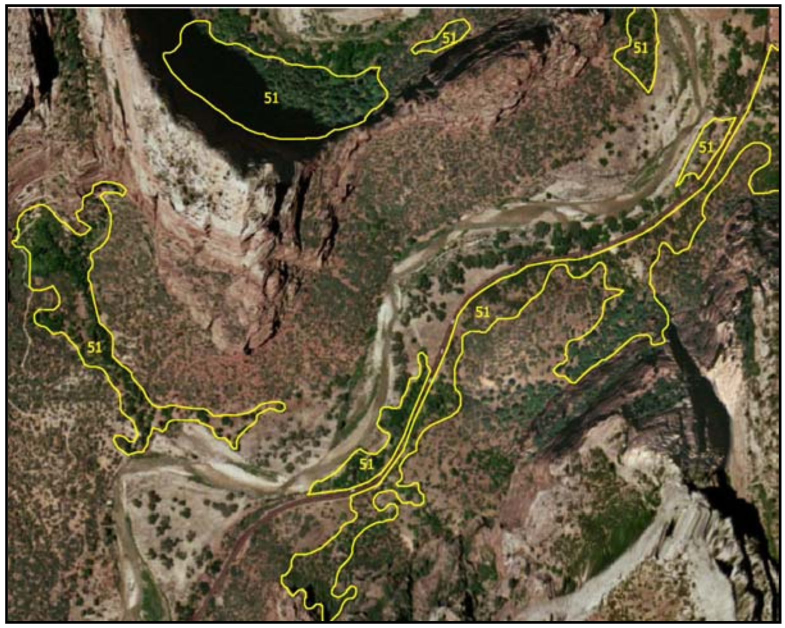
51 *Populus fremontii – Fraxinus velutina* Woodland
Fremont Cottonwood – Velvet Ash Woodland

Association:
-Populus fremontii - Fraxinus velutina Woodland

Common species:
Fraxinus velutina
Populus fremontii
Acer negundo
Quercus gambelii
Bromus diandrus
Bromus tectorum

Project Specifics:
Frequency = 800 total polygons
548 polygons ZION, 252 polygons Environs
Area = 1,627 total acres
1,136 acres ZION, 491 acres Environs
Average Size = 2 acres

Photo Signature Example



Description:
This map class strived to account for the high species diversity found in the floodplain and riparian deciduous woodlands found throughout the project area. In these stands various mixes of tree species could occur including cottonwood, boxelder, velvet ash, single-leaf ash, and gambel oak. Although only cross-walked to one association this map class actually represented mosaics of many other deciduous woodland types as well. The intricate intermingling of species and sudden change in composition between stands made mapping individual associations impossible. On the aerial photos this type appeared as mottled dark or bright green and occurred in canyon bottoms and on floodplain terraces. This type was distinguished from the Fremont Cottonwood Woodland Complex map class by the presence of other tree species and their corresponding different photo signature tones.

Ground Photos

52 *Elaeagnus angustifolia* Semi-natural Woodland
Russian Olive Semi-natural Woodland

Association:
-*Elaeagnus angustifolia* Semi-natural Woodland

Common species:
Elaeagnus angustifolia
Salix exigua
Populus fremontii
Tamarix spp

Project Specifics:
Frequency = 43 total polygons
1 polygons ZION, 42 polygons Environs
Area = 73 total acres
0.7 acres ZION, 72 acres Environs
Average Size = 2 acres

Photo Signature Example

Description:
This map class is limited to one known location in ZION but is more prevalent outside the Park on the Virgin River Floodplain. The blue-gray color of the Russian olive foliage is very distinctive on the true color aerial photography. In some places, small patches may have been over looked or mapped as another deciduous floodplain woodland map classes. In the Environs this type often intermingled with the salt cedar shrubland map class.

Ground Photo

Deciduous Forests

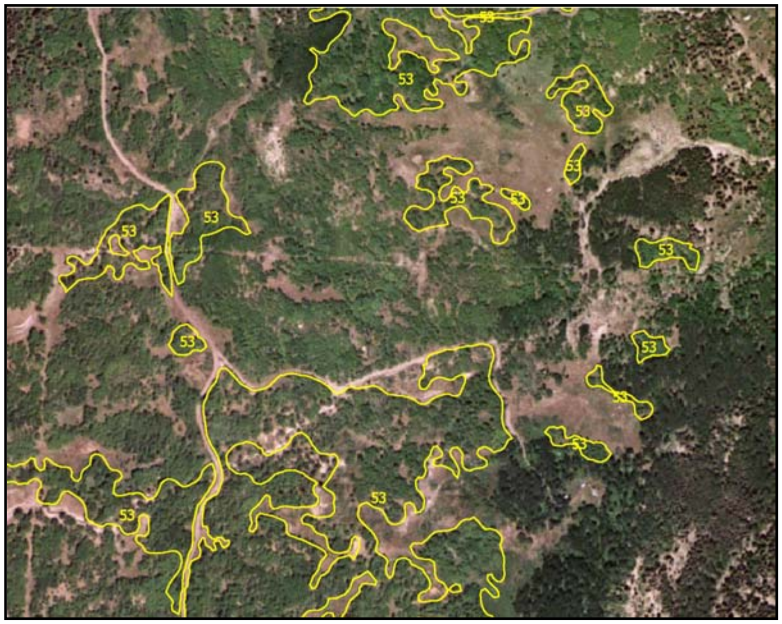
53 *Quercus gambelii* Woodland
Gambel Oak Woodland

Associations:
-*Quercus gambelii / Amelanchier utahensis* Shrubland
-*Quercus gambelii / Artemisia tridentata* Shrubland
-*Quercus gambelii - Cercocarpus montanus / (Carex geyeri)* Shrubland
-*Quercus gambelii / Symphoricarpos oreophilus* Shrubland
-*Quercus gambelii / Poa fendleriana* Shrubland

Common species:
Quercus gambelii
Artemisia tridentata
Poa fendleriana
Symphoricarpos oreophilus
Cercocarpus montanus
Carex geyeri
Amelanchier utahensis

Project Specifics:
Frequency = 1568 total polygons
780 polygons ZION, 788 polygons Environs
Area = 4,479 total acres
2,046 acres ZION, 2,433 acres Environs
Average Size = 3 acres

Photo Signature Example



Description:
This map class is identical to the gambel oak shrubland map class except for the structure of the gambel oak. On the aerial photos the woodland form appeared taller and usually occurred in more mesic areas such as valleys, floodplains, and north-facing footslopes. In a majority of cases, this type had a closed canopy preventing understory species from being interpreted from the aerial photography. The presence of bigtooth maple was all that separated this map class from the Bigtooth Maple / Gambel Oak Forest map class and led to some confusion when the maple was in low abundance.

Ground Photos

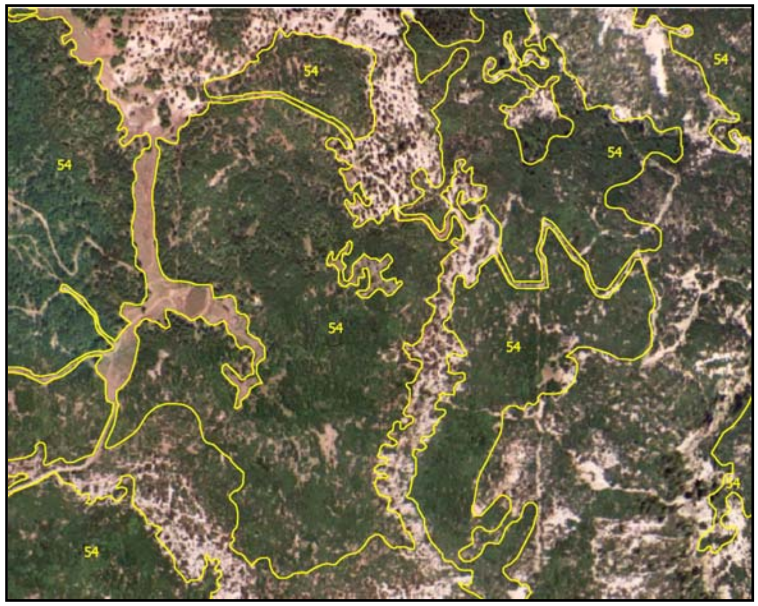
54 *Acer grandidentatum / Quercus gambelii* Forest
Bigtooth Maple / Gambel Oak Forest

Association:
-Acer grandidentatum – Quercus gambelii Forest

Common Species:
Prunus viriginiana
Rosa woodsii
Symphoricarpos oreophilus
Physiocarpus malvaceus
Berberis repens

Project Specifics:
Frequency = 331 total polygons
98 polygons ZION, 233 polygons Environs
Area = 9,130 total acres
1,362 acres ZION, 7,768 acres Environs
Average Size = 28 acres

Photo Signature Example



Description:
This map class generally occurs on middle and lower slopes with northern aspects in the higher areas of ZION. It is distinguished from the other gambel oak types by the high percentage of bigtooth maple; 50-50 in some cases. In dryer areas the maple disappears and transitions to a gambel oak woodland type. Aspen and white fir may intermingle with this class.

Ground Photos

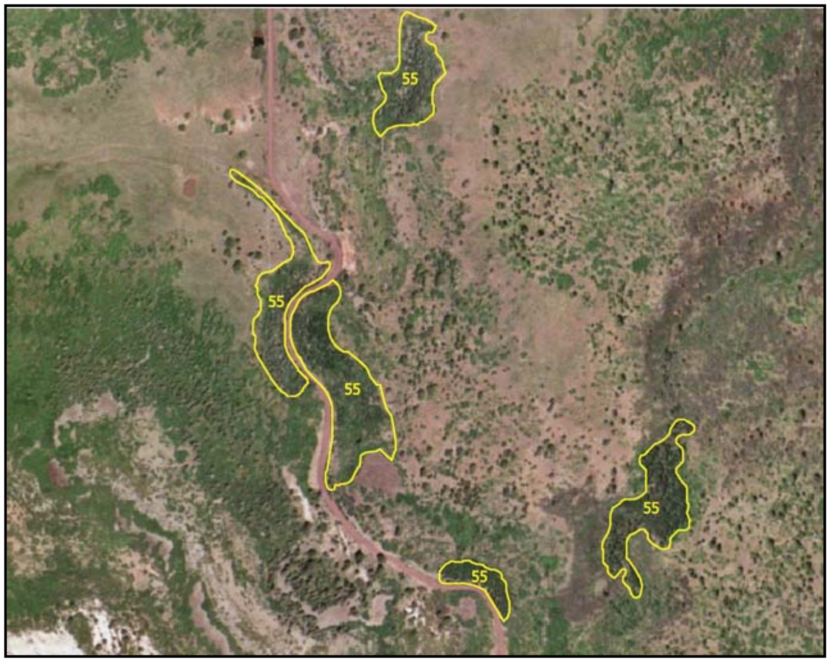
55 *Populus tremuloides* Forest Complex
Quaking Aspen Forest Complex

Associations:
-Populus tremuloides - Abies concolor / Symphoricarpos oreophilus Forest
-Populus tremuloides - Abies concolor / Poa pratensis Forest
-Populus tremuloides / Symphoricarpos oreophilus / Tall Forbs Forest
-Populus tremuloides / Quercus gambelii / Symphoricarpos oreophilus Forest

Common species:
Abies concolor
Populus tremuloides
Acer grandidentatum
Symphoricarpos oreophilus
Poa pratensis
Achillea millefolium
Vicia americana

Project Specifics:
Frequency = 482 total polygons
99 polygons ZION, 383 polygons Environs
Area = 2,693 total acres
297 acres ZION, 2,396 acres Environs
Average Size = 6 acres

Photo Signature Example



Description:
This map class is fairly common in the northern portions of the project area in cool, moist areas. Quaking aspen occurs in many different forms including old, decadent stands, lush post-burn suckers, and thick pole-sized clumps. The appearance of the aspen on the aerial photos was characterized by a smooth, dark green color and white trunks (if the canopy was open). This map class intermingled with various other montane forest and woodland types, including white fire and gambel oak.

Ground Photos

Coniferous Woodlands

56 *Juniperus spp. / Artemisia tridentata* Woodland Complex
Juniper / Big Sagebrush Woodland Complex

Associations:
-Juniperus osteosperma / Artemisia tridentata Woodland
-Pinus edulis - Juniperus spp. / Artemisia tridentata Woodland
-Pinus monophylla - Juniperus osteosperma / Artemisia tridentata Woodland

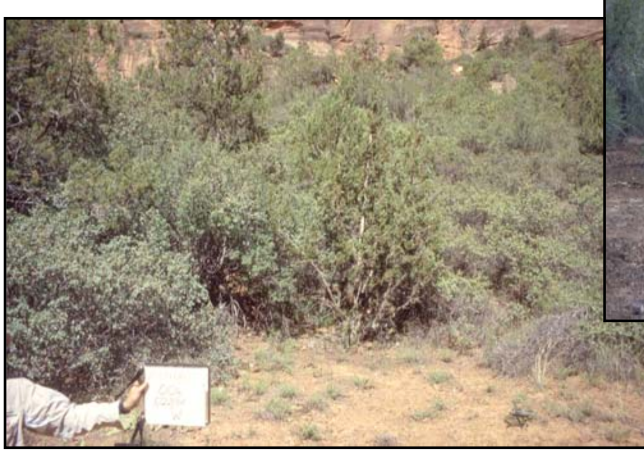
Common species:
Juniperus osteosperma
Artemisia tridentata
Ephedra nevadensis
Gutierrezia sarothrae
Opuntia macrorhiza

Project Specifics:
Frequency = 624 total polygons
203 polygons ZION, 421 polygons Environs
Area = 6216 total acres
2,298 acres ZION, 3,918 acres Environs
Average Size = 10 acres

Photo Signature Example

Description:
This map class is common in the southern regions of the project area where the pinyon pine tends to be less abundant, likely a result of drier conditions. *Juniperus osteosperma* is usually less than 25% cover in and will range between 5-10 m in height. The herbaceous layer is absent or very sparse. The presence of big sagebrush in the understory was a diagnostic characteristic on the aerial photographs. This map class may intermingle and be confused with the other pinyon – juniper map classes especially if shrubs other than big sagebrush are prominent.

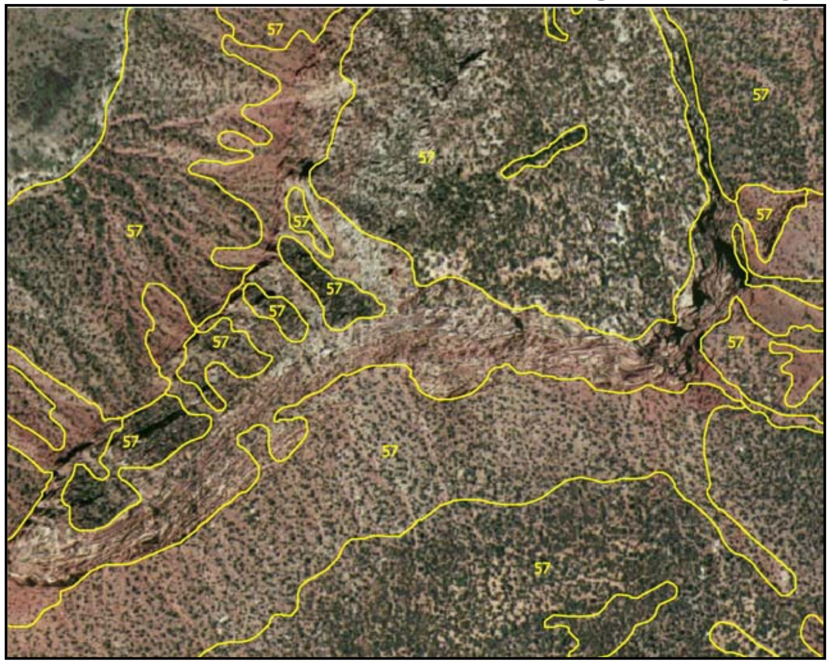
Ground Photos



57 *Pinus* spp. - *Juniperus* spp. Woodland Complex
Pinyon - Juniper Woodland Complex

Associations:
-Pinus edulis - Juniperus osteosperma / Cercocarpus intricatus Woodland
-Pinus edulis - Juniperus osteosperma / Purshia stansburiana Woodland
-Pinus edulis - Juniperus osteosperma / Arctostaphylos patula Woodland
-Pinus edulis - Juniperus osteosperma / Cercocarpus montanus Woodland
-Pinus edulis - Juniperus osteosperma / Cercocarpus ledifolius Woodland
-Pinus monophylla - Juniperus osteosperma / Artemisia nova Woodland
-Pinus monophylla - Juniperus osteosperma / Quercus turbinella Woodland
-Pinus monophylla - Juniperus osteosperma / (Shepherdia rotundifolia Amelanchier utahensis) Woodland
-Pinus monophylla - Juniperus osteosperma / Cercocarpus montanus - Quercus gambelii Woodland
-Pinus monophylla - Juniperus osteosperma / Gutierrezia sarothrae Woodland
-Pinus monophylla - Juniperus osteosperma / Pleuraphis jamesii Woodland
-Pinus monophylla - Juniperus osteosperma / Coleogyne ramosissima Woodland

Photo Signature Example



Common species:
Amelanchier utahensis
Arctostaphylos patula
Cercocarpus montanus
Cercocarpus intricatus
Purshia stansburiana
Cercocarpus ledifolius
Quercus turbinella
Shepherdia rotundifolia
Gutierrezia sarothrae
Pleuraphis jamesii
Coleogyne ramosissima

Ground Photos

Project Specifics:
Frequency = 2,379 total polygons
1,594 polygons ZION, 785 polygons Environs
Area = 55,995 total acres
34,323 acres ZION, 21,672 acres Environs
Average Size = 24 acres

Description:

This is the largest map unit at ZION coving over 20% of the project area. Many of the polygons represent differences in density due to changes in soils, moisture levels, and slope/aspect. This class constitutes the majority of the pinyon pine and juniper associations found at ZION. Due to the similar growth patterns and hybridizing between the two pine species it was impossible to sort *Pinus monophylla* from *P. edulis* on the aerial photos. Throughout most of the Park, this map class intermingles and can be confused with similar ponderosa pine map classes, especially if the ponderosa trees are small and grow at the same height as the pinyon pines and junipers. Both pinyon-juniper and ponderosa pine map classes can share the same understory species.

58 *Pinus spp. - Juniperus spp. / Quercus gambelii* Woodland Complex
Pinyon - Juniper / Gamble Oak Woodland Complex

Associations:
-Juniperus scopulorum - Quercus gambelii Woodland
-Pinus edulis - Juniperus spp. / Quercus gambelii Woodland

Common species:
Juniperus osteosperma
Pinus edulis
Amelanchier utahensis
Arctostaphylos patula
Cercocarpus montanus
Quercus gambelii
Poa fendleriana

Project Specifics:
Frequency = 1,875 total polygons
1,084 polygons ZION, 791 polygons Environs
Area = 14,786 total acres
7,112 acres ZION, 7,674 acres Environs
Average Size = 8 acres

Photo Signature Example

Description:
This is a fairly common map unit at ZION representing situations were pinyon-juniper woodlands have substantial cover of gambel oak in the understory. Most stands are fairly large and occur on flat to moderately steep slopes of mesas and across large plateaus. The aspects of these slopes are generally eastern to southern, and occasionally western. When the amount of pinyon-juniper is low this type may be confused with other gambel oak map classes and when gambel oak is reduced it may appear as other pinyon-juniper woodlands.

Ground Photos

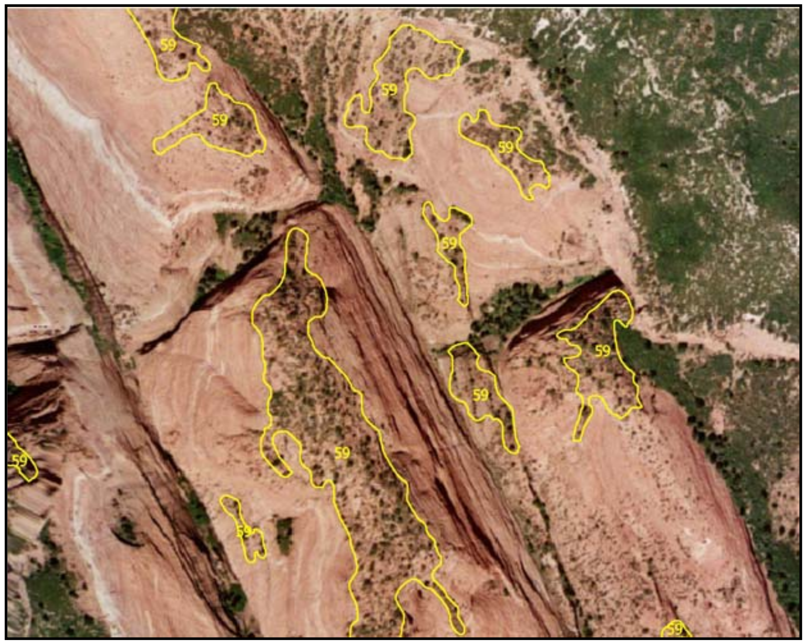
59 *Pinus ponderosa* Slickrock Sparse Vegetation
Ponderosa Pine Slickrock Sparse Vegetation

Association:
-*Pinus ponderosa* Slickrock Sparse Vegetation

Common species:
Pinus ponderosa
Pinus monophylla
Amelanchier utahensis
Arctostaphylos patula
Cercocarpus intricatus
Aristida purpurea
Poa fendleriana
Sporobolus cryptandrus
Comandra umbellate
Heterotheca villosa
Phlox austromontana
Stephanomeria spp.

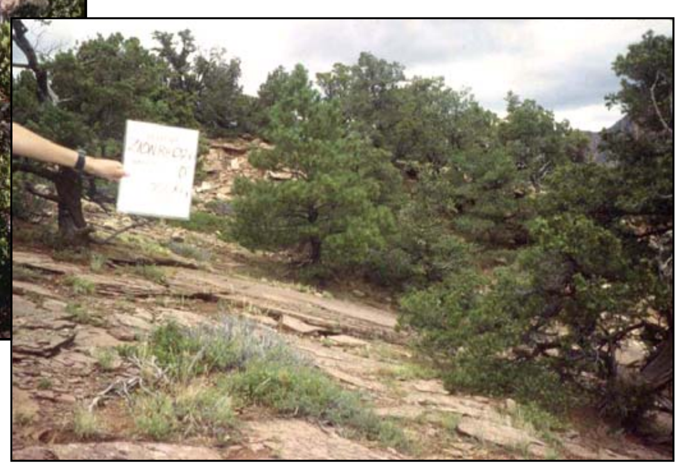
Project Specifics:
Frequency = 816 total polygons
746 polygons ZION, 70 polygons Environs
Area = 5,726 total acres
4,922 acres ZION, 804 acres Environs
Average Size = 7 acres

Photo Signature Example



Description:
This association occurs on steep Navajo sandstone slopes above 6000 feet elevation. Sandy soils accumulate in rock crevices to support opportunistic vegetation. There is high cover of exposed bedrock with occasional manzanita and mountain mahogany shrubs. This map class is usually in close proximity to the barren Navajo map class and if the ponderosa pine is extremely low in cover may be confused with other slickrock sparse shrub types. In some areas with shadows and/or poor light this map class may appear very similar on aerial photos to the *Pinus ponderosa / Arctostaphylos patula* Woodland class.

Ground Photos



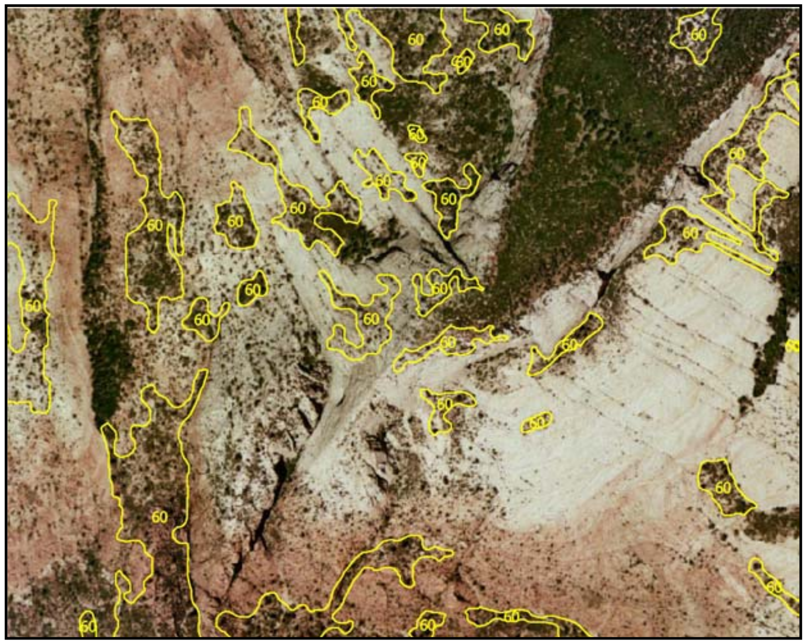
60 *Pinus ponderosa / Arctostaphylos patula* Woodland
Ponderosa Pine / Greenleaf Manzanita Woodland

Association:
-Pinus ponderosa / Arctostaphylos patula Woodland

Common species:
Juniperus osteosperma
Pinus edulis, Pinus ponderosa
Amelanchier utahensis
Arctostaphylos patula
Cercocarpus montanus
Purshia tridentate
Quercus gambelii
Quercus turbinella

Project Specifics:
Frequency = 2,434 total polygons
1,979 polygons ZION, 455 polygons Environs
Area = 21,531 total acres
15,744 acres ZION, 5,787 acres Environs
Average Size = 9 acres

Photo Signature Example



Description:
This map class is widespread throughout ZION occurring on gentle to moderate slopes of various aspects at elevations between 5600 and 8000 feet. It is found on high mesa tops, plateaus and Navajo sandstone formation benches and basins. The photo signature for this class is distinct due to the open canopy of the ponderosa pine trees and the olive-green color of the manzanita. This type may intermingle with other manzanita and sparse shrub types common on slickrock and Navajo sandstone formations.

Ground Photos

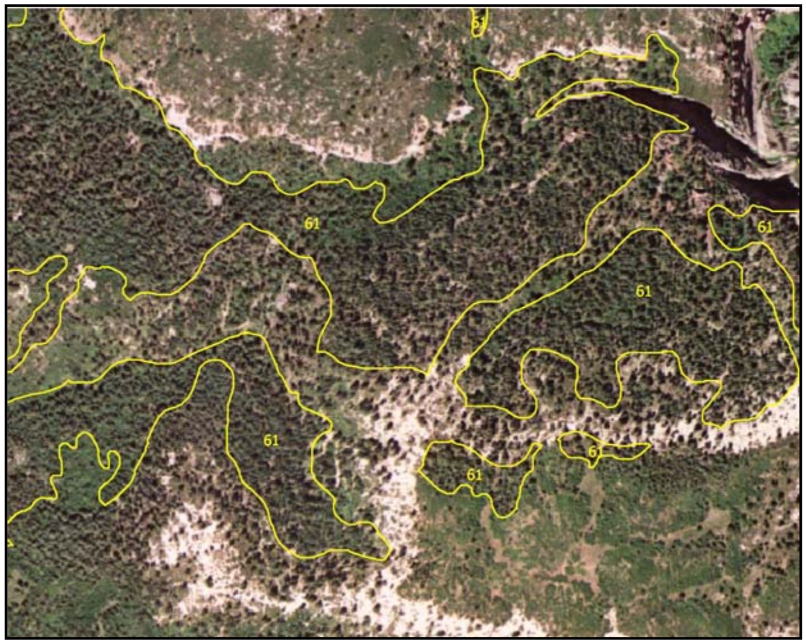
61 *Pinus ponderosa / Quercus gambelii* Woodland Complex
Ponderosa Pine / Gambel Oak Woodland Complex

Associations:
-Pinus ponderosa / Quercus gambelii Woodland
-Pinus ponderosa / Pteridium aquilinum Woodland [Provisional]

Common species:
Juniperus scopulorum
Pinus ponderosa
Arctostaphylos patula
Quercus gambelii
Pteridium aquilinum

Project Specifics:
Frequency = 2,185 total polygons
1,730 polygons ZION, 455 polygons Environs
Area = 12,438 total acres
8,763 acres ZION, 3,675 acres Environs
Average Size = 6 acres

Photo Signature Example



Description:
This is a widespread woodland type at ZION. The vast majority of this type represents *Pinus ponderosa / Quercus gambelii* Woodland association with a prominent gambel oak understory that appears bright green on the aerial photos. In some limited situations a dense understory of bracken fern gives the same aerial photo signature. This occurs primarily across the Pine Valley and Pocket Mesa areas. This class is rather unique and usually occurs adjacent to other gambel oak types.

Ground Photos

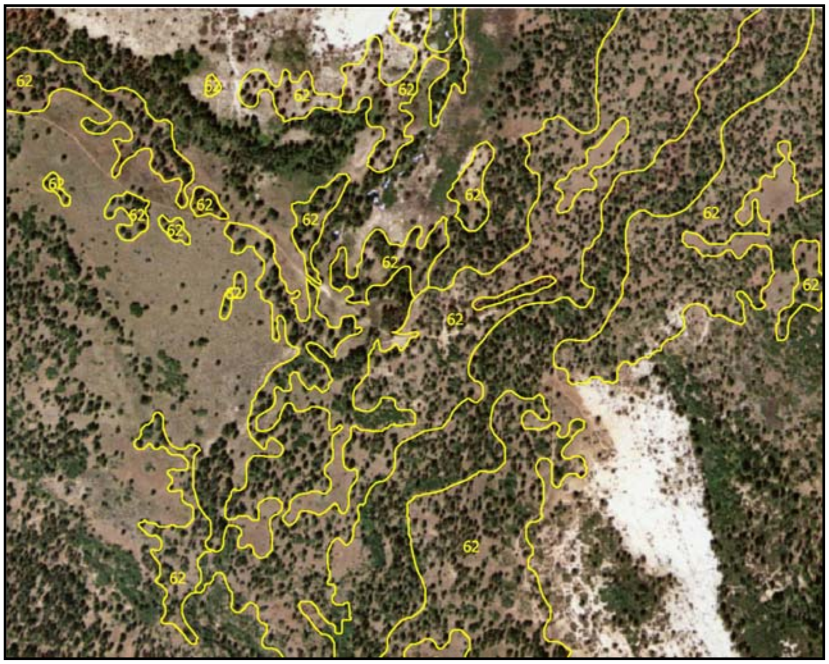
62 *Pinus ponderosa* / Mixed Herbaceous Woodland Complex
Ponderosa Pine / Mixed Herbaceous Woodland Complex

Associations:
-Pinus ponderosa / Bromus inermis Semi-natural Woodland
-Pinus ponderosa / Artemisia nova Woodland

Common species:
Pinus ponderosa
Quercus gambelii
Artemisia nova
Carex rossii
Elymus elymoides
Poa secunda
Bromus inermis
Heterotheca villosa
Lupinus argenteus
Lotus utahensis
Achillea millefolium

Project Specifics:
Frequency = 177 total polygons
113 polygons ZION, 64 polygons Environs
Area = 926 total acres
608 acres ZION, 317 acres Environs
Average Size = 5 acres

Photo Signature Example



Description:
This map class is fairly rare in the project area but can be locally abundant in recently burned or disturbed areas. *Pinus ponderosa* dominates this association with rather low cover (10-30%). The understory on the aerial photos appears devoid of shrubs although when *Artemisia nova* is over 20% cover it may appear slightly gray. The understory is usually evenly distributed in the stand. Specifically in Corral Hollow the spring snowmelt provides seasonally saturated soils that favor *Bromus inermis* and *Poa pratensis*.

Ground Photos

Coniferous Forests

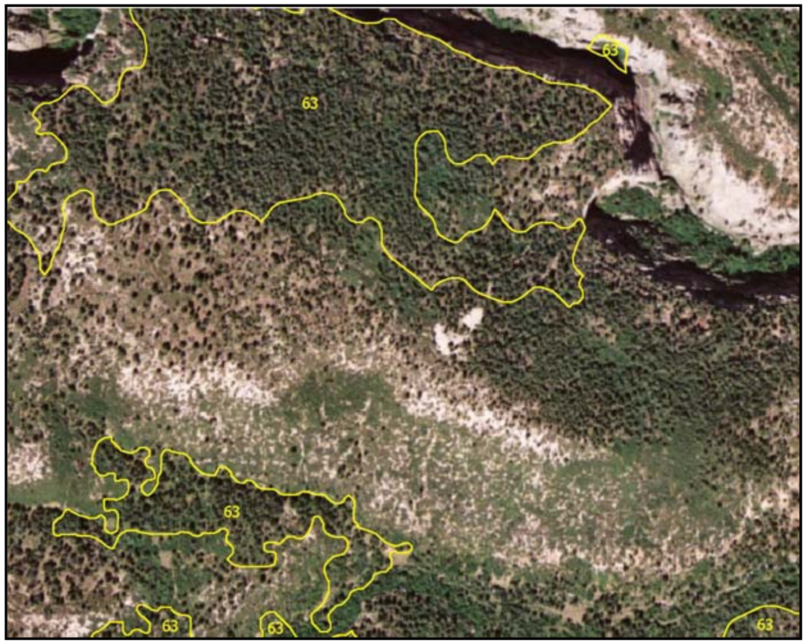
63 *Pinus ponderosa* Forest (Closed Canopy)
Ponderosa Pine Forest (Closed Canopy)

Associations:
(none; map class cannot be classified to the association level)

Common species:
Pinus ponderosa

Project Specifics:
Frequency = 43 total polygons
26 polygons ZION, 17 polygons Environs
Area = 628 total acres
242 acres ZION, 386 acres Environs
Average Size = 15 acres

Photo Signature Example

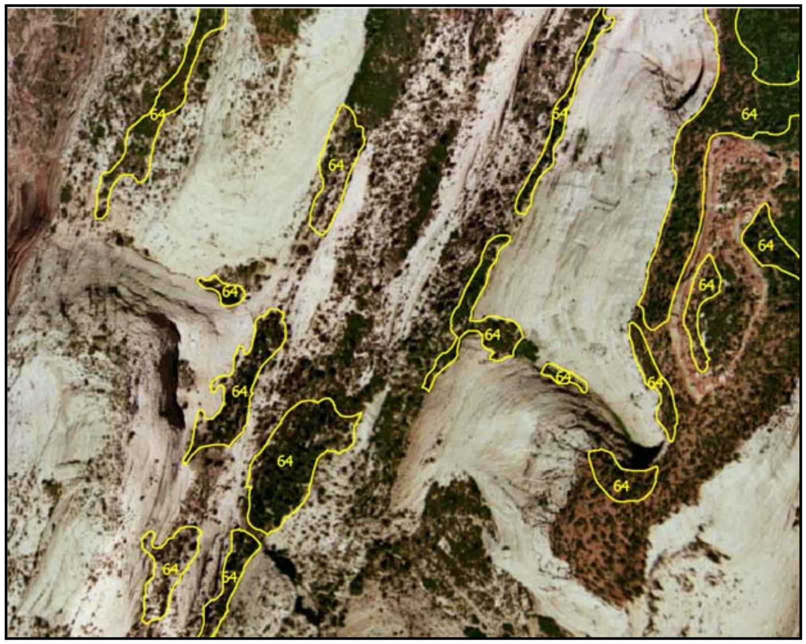


Description:
This map class is fairly rare at ZION and occurs mainly on well developed soils in remote areas of the Park. In these situations the pine trees grow close together forming thick, dog-hair stands. Since the canopy is tight, understory species can not be determined from the aerial photos. On the ground, the understory is also usually sparse or absent. Often a thick layer of needles is present. This map class may be similar to other thick ponderosa pine types.

Ground Photos

64 *Pseudotsuga menziesii* Forest Alliance
Douglas-fir Forest Alliance

Photo Signature Example



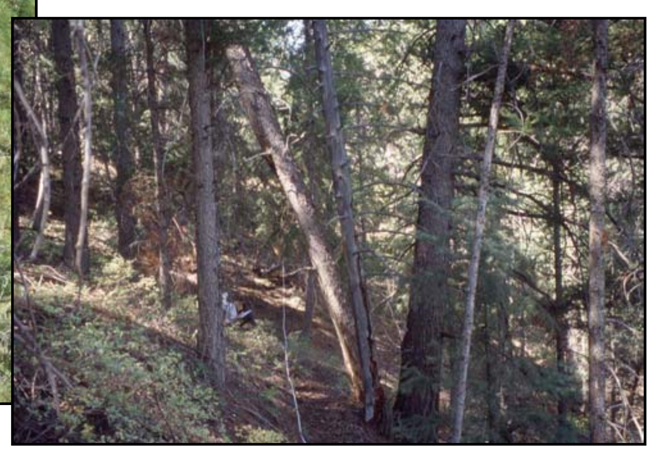
Associations:
-Pseudotsuga menziesii / Quercus gambelii Forest
-Pseudotsuga menziesii / Symphoricarpos oreophilus Forest
-Pseudotsuga menziesii / Acer grandidentatum Forest

Common species:
Pseudotsuga menziesii
Acer grandidentatum
Quercus gambelii
Mahonia repens
Paxistima myrsinites
Maianthemum stellatum
Thalictrum fendleri
Pinus ponderosa
Amelanchier utahensis
Symphoricarpos oreophilus

Project Specifics:
Frequency = 600 total polygons
552 polygons ZION, 48 polygons Environs
Area = 1,849 total acres
1,718 acres ZION, 131 acres Environs
Average Size = 3 acres

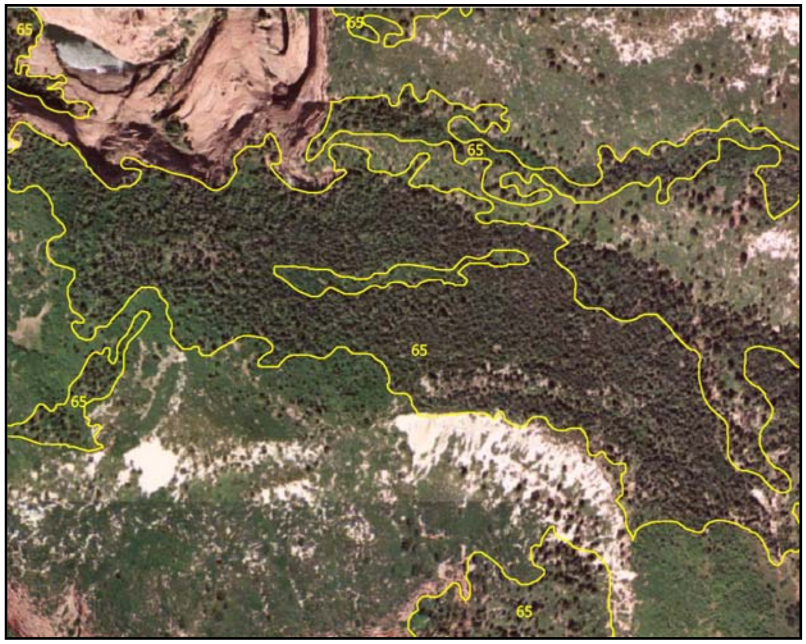
Description:
This map class is dominated by mature *Pseudotsuga menziesii* common in moist valleys, ravines and slot canyons. Occasional stands may also exist in cool floodplains and on elevated canyon shelves and ridges. *Pinus ponderosa* and/or *Abies concolor* are occasionally present and may replace *Pseudotsuga menziesii* as the local dominant. The indicator shrub *Symphoricarpos oreophilus* is at least present, but with insignificant cover. *Amelanchier utahensis* is usually present in the shrub layer. Herbaceous species are diverse and contribute minimal cover. Mature *Juniperus scopulorum* and *Quercus gambelii* may also be present or represented in the subcanopy by young trees and seedlings. This class is easily confused with the *Abies concolor* Forest Alliance due to the similar growth habits of the dominant conifers.

Ground Photos



65 *Abies concolor* Forest Alliance
White Fir Forest Alliance

Photo Signature Example



Associations:
-*Abies concolor / Acer grandidentatum*
-*Abies concolor / Quercus gambelii* Forest
-*Abies concolor / Symphoricarpos oreophilus* Forest

Common species:
Abies concolor
Pseudotsuga menziesii
Acer grandidentatum
Quercus gambelii.
Pinus strobiformis,
Pinus ponderosa
Juniper spp.
Amelanchier alnifolius,
Symphoricarpos oreophilus,
Populus tremuloides

Project Specifics:
Frequency = 451 total polygons
290 polygons ZION, 161 polygons Environs
Area = 5,194 total acres
2,333 acres ZION, 2,861 acres Environs
Average Size = 12 acres

Description:
This map class is widespread at ZION and occurs in two distinct habitats. In cool, wet canyons it appears as linear patches, often replacing Douglas fir as the dominant. Throughout the higher elevations this type occurs on cool, dry middle and lower slopes and on all aspects except south and southwestern. Stands transition to the Pinus *ponderosa / Quercus gambelii* Forest in dryer sites. Large stands in the Northwest intermingle with *Populus tremuloides*.

Ground Photos